NASA CR-54281

fx apd 3/14/66

JUN 11 1965

N66-19512

FACILITY FORM 602

(ACCESSION NUMBER)	(THRU) 1
57 (PAGES)	(CODE)
CR 54284 (NASA CR OR TMX OR AD NUMBER)	32 (CATEGORY)

GPO PRICE $ ______

CFSTI PRICE(S) $ ______

Hard copy (HC) 3.00

Microfiche (MF) .50

ff 653 July 65

GD

GENERAL DYNAMICS

~~ASTRONAUTICS~~

NOW COMBINED WITH CONVAIR

A2136-1 (REV. 6-61)

FLIGHT-WIND RESTRICTIONS PROCEDURE, ATLAS/CENTAUR AC-6 THROUGH AC-15

Report Number GD/C-BTD65-068
15 May 1965

Contract Number NAS3-3232

Prepared by R T Mattson
R. T. Mattson
Dynamics Engineer

Technical Approval by R. E. Martin
R. E. Martin
Chief of Dynamics

Centaur Project Approval by RS Wentink
R.S. Wentink
Assistant Chief Engineer
Design Analysis

GENERAL DYNAMICS
CONVAIR DIVISION
San Diego, California

The following persons and/or their engineering groups have been instrumental in preparing the information in this document. It is published with their concurrence; and any questions concerning it should be directed to them.

		Department	Extension
R. L. Holt	Design Specialist	Dynamics 585-1-2	4655
A. F. Leondis	Design Specialist	Dynamics 585-1-2	4674
C. D. Pengelley	Senior Dynamics Group Engineer	Dynamics 585-1	3295

Additional copies of this document may be obtained by contacting Centaur Resources Control and Technical Reports, Department 954-4, Building 26, Kearny Mesa Plant, San Diego, California.

FOREWORD

This report has been prepared and published in compliance with the provisions of Contract NAS3-3232 which specify structural dynamic-loads and design-determination requirements as outlined in Item 148 of the Centaur Documentation Requirements Plan, Report Number 55-00207E, dated 11 January 1965 (General Dynamics/Convair).

This report presents a procedure for rapidly analyzing the measured wind profile prior to launch. This procedure presents a means of obtaining a greater percentage of days which are suitable for launching the Atlas/Centaur vehicle than those possible with a simplified wind-restriction procedure.

SUMMARY

19512

The majority of loads which can be applied to the Atlas/Centaur vehicle in flight can be calculated well in advance of the vehicle's launch date. One effect, however, that of the prevailing atmospheric wind conditions, hereafter called the wind profile, must be accounted for just prior to launch if success is to be assured during marginal weather.

The starting point of the analysis is the ultimate structural capability of the vehicle. This capability, determined from the vehicle's as-built condition, is used in conjunction with the pre-calculated loads and with the loads obtained using the flight-wind profile in order to determine whether the vehicle can be safely launched. The method employed is the same as that used for the AC-4 vehicle. This method employs the calculated axial load in addition to the calculated bending moments, both being dependent upon the wind profile. Considered also are the vehicle's ultimate bending moments and axial loads and their respective factors of safety. A 30-fps gust is used in the AC-6 simulation program. A rapid analysis on the IBM 7094 computer, combined with rapid analysis of output film on a Stromberg-Carlson 4020 microfilm recorder unit, comprises the basis of a recommendation relayed to the launch complex within minutes after obtaining the flight-wind profile.

Sections I through IV give the background of the problem, the flight simulation and launch availability details, and a presentation of the results.

A detailed outline of the complete prelaunch procedure, including criteria for launch recommendations, is presented in Section V.

In conclusion, a simplified backup procedure for plotting and evaluating the wind profile directly at ETR will be presented as Addendum I to this report. The backup procedure is to be used only in case of computer or communications breakdown. This procedure will generally ensure booster-vehicle structural integrity as it flies through winds determined by a sounding made just prior to launch. Instead of relying on an IBM 7094 computer, the simplified procedure employs an IBM 1401, or hand calculations, and gives slightly conservative results.

Bending moments at three vehicle stations are possibly critical. Hence in the backup procedure, allowable values are compared with calculated values to determine a launch recommendation; and engine deflection is ignored, since bending moment loads are almost always more critical.

author

Any revisions and changes which it may become necessary to make to this report will be forwarded only to those persons whose names appear on the distribution list at the end of the report.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION I

INTRODUCTION

1.1 STATEMENT OF THE PROBLEM

1.1.1 LAUNCH LIMITING FACTORS. An appreciable proportion of the total load applied to any booster vehicle during the first stage of flight is caused by the wind profile through which it flies. These loads usually dictate the design of a great deal of the vehicle's structure. The Atlas/Centaur vehicle was designed on the basis of minimum modification to the Atlas booster. Therefore, Atlas/Centaur is not structurally capable of flight through the extremely high-force winds, which have a very remote probability of occurrence, that were used as design criteria for the Atlas ICBM. There is a serious lack of good gust data for vertically rising vehicles and substantial inaccuracy in present wind measuring techniques. This fact further reduces the number of days suitable for a launch, under the ground rule that launches shall take place only under those wind conditions in which approximately 100-percent probability of structural integrity can be guaranteed.

1.1.2 PRIMARY PROCEDURE. It is imperative, therefore, that the most accurate procedure possible be used to predict flight-wind loads for each Atlas/Centaur flight if the maximum number of days suitable for launching are to be obtained. This report presents a detailed procedure for monitoring winds prior to launch and for predicting flight-wind loads upon which the decision to launch can be based.

1.1.3 ALTERNATE PROCEDURE. The magnitude and time of maximum bending moment due to wind is a function of the complete time history of the wind, not merely of its instantaneous velocity or shear value. Also the vehicle allowables are a function of time. Therefore, it is impossible to accurately predict flight loads only on the basis of quantities measured from the wind profile. A backup measure to be used only in case of a computer or communications breakdown in the primary procedure will be presented in Addendum I to this report.

1.2 FLIGHT-WIND RESTRICTION PROCEDURE

1.2.1 ULTIMATE ALLOWABLES. The procedure to be used for flights AC-6 through 15 in order to determine flight-wind profiles suitable for launch is the same as the method used on AC-4 and 5. Structures Engineering determines the ultimate allowable axial loads and bending moments of the vehicle on the basis of its as-built condition at launch time. The axial loads and bending moments due to the flight-wind profile are then calculated through use of the trajectory simulation program. The calculated axial loads and bending moments are multiplied by their respective factors of safety, divided by the respective ultimate allowables, summed, and compared to unity. A value greater than unity indicates that the vehicle structural integrity would be jeopardized if the vehicle were launched.

1.2.2 THE CALCULATED BENDING MOMENT. The calculated bending moment arises from random loads and wind-profile loads. The random loads are caused by rigid- and elastic-body gusts, and deviations in drag, axial acceleration, angle of attack, and dynamic pressure due to dispersions in basic parameters. The random loads due to deviations are converted to equivalent bending moments, root-sum-squared with the gust bending moments, and added to the wind-profile bending moment. The basic parameters include thrust, launch weight, specific impluse, pitch-program voltage, propellant sloshing, and buffeting.

1.2.3 THE CALCULATED AXIAL LOAD. The calculated axial loads are made up of loads due to axial acceleration and to drag, which are calculated during the flight simulation, using the actual dynamic pressure which is induced by the flight-wind profile.

1.2.4 CRITERIA ALLOWANCES. It is the intent of this report to make conservative allowances for uncertainties in the foregoing loads and for errors in the technique of wind measurement. These allowances are such that the Load Capability Ratio can safely reach 100-percent of the ultimate with no other factors applied for the flight.

1.3 CONFIGURATION APPLICABILITY

1.3.1 AC-6 CONFIGURATION. Though the general procedures of this report are not expected to change for the next 10 vehicles, the specific data displayed in the graphs of Section II and in Table 3-1 are applicable to the AC-6 flight only. The nose fairing and insulation panels are to be jettisoned as before. However, this will be the first time that an Atlas/Centaur vehicle has traversed the atmosphere using booster engines with 165,000 pounds of thrust. The payload is a Surveyor dynamic model having a retro-motor simulator. The model is to be separated from the Centaur. In addition to the payload, several telemetry channels and associated measuring devices will be on board for R&D purposes.

1.3.2 FUTURE CONFIGURATIONS. Future configurations should not differ greatly from the AC-6 configuration. Also the digital computer program method used in this procedure will be the same for future flights. Therefore this report is considered applicable for flights AC-6 through AC-15. Relatively minor changes in vehicle parameters, coefficients, gust response, etc., will be made, if necessary, for each vehicle without changing the report. Should a major configuration or program change occur, however, this report will be revised.

SECTION II

SOURCES OF VARIOUS INPUT BENDING MOMENTS

2.1 SOURCE OF BENDING MOMENT DUE TO GUSTS AND DEVIATIONS

2.1.1 GUST BENDING MOMENT BASIC CALCULATIONS. A 30 fps (1-cos) shaped gust is applied normal to the vehicle, and the total rigid-body and elastic-body responses determined. The angle of attack is calculated using the vehicle velocity relative to the average expected wind profile.

2.1.2 DATA. This calculation is done in the program presented in Reference 2-1, using flight parameters at 44, 52, 60, 68, 72, 76, and 84 seconds after liftoff for the initial conditions (Reference 2-2). This program utilizes:

a. The first five structural bending modes

b. The first slosh mode in all tanks

c. A third-order actuator

d. A second-order rate gyro

e. Aeroelastic coupling with quasi-steady coefficients

f. Complete autopilot and filters.

The gust is assumed to envelop the entire height of the vehicle instantaneously and to act normal to the vehicle in both the pitch and yaw planes. The wavelengths of the gusts which have been investigated varied in length from 100 to 1,000 feet.

A 30-fps gust magnitude, as given in Reference 2-3, is believed to be sufficiently severe to represent low wavelength atmospheric turbulence, measurement errors, and the change in the wind profile between the time of measurement and the time of the Atlas/Centaur flight. Smoke-trail wind measurements have shown shear reversals (equivalent to gusts of long wavelength) which reach velocities on the order of 25-fps greater than that indicated by balloon data. The maximum gust wavelength is taken equal to increments at which balloon-sounding data are furnished. Figures 2-1 and 2-2 show the bending moment due to gusts versus time. Each of five selected stations is represented parametrically. This increment of bending moment will be used in deriving the Load Capability Ratio in Section III. The corresponding engine deflections (in pitch and yaw) due to gusts are shown in Figure 2-3.

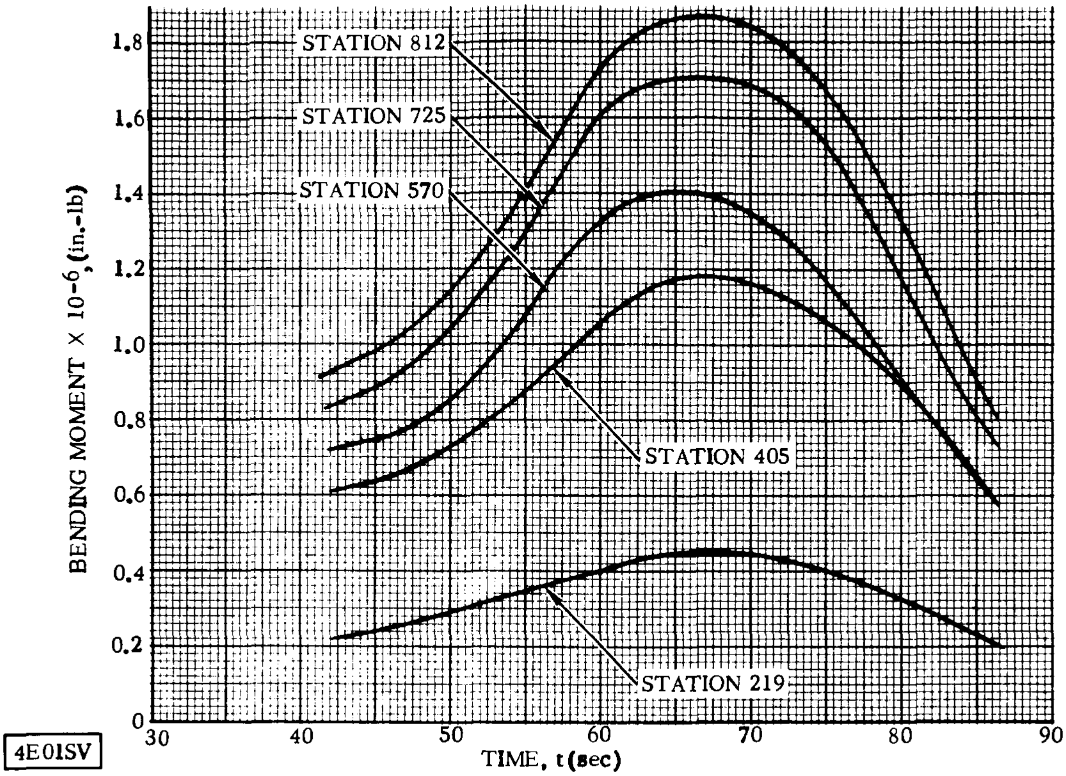


Figure 2-1. Bending Moment due to Gust in Pitch versus Time

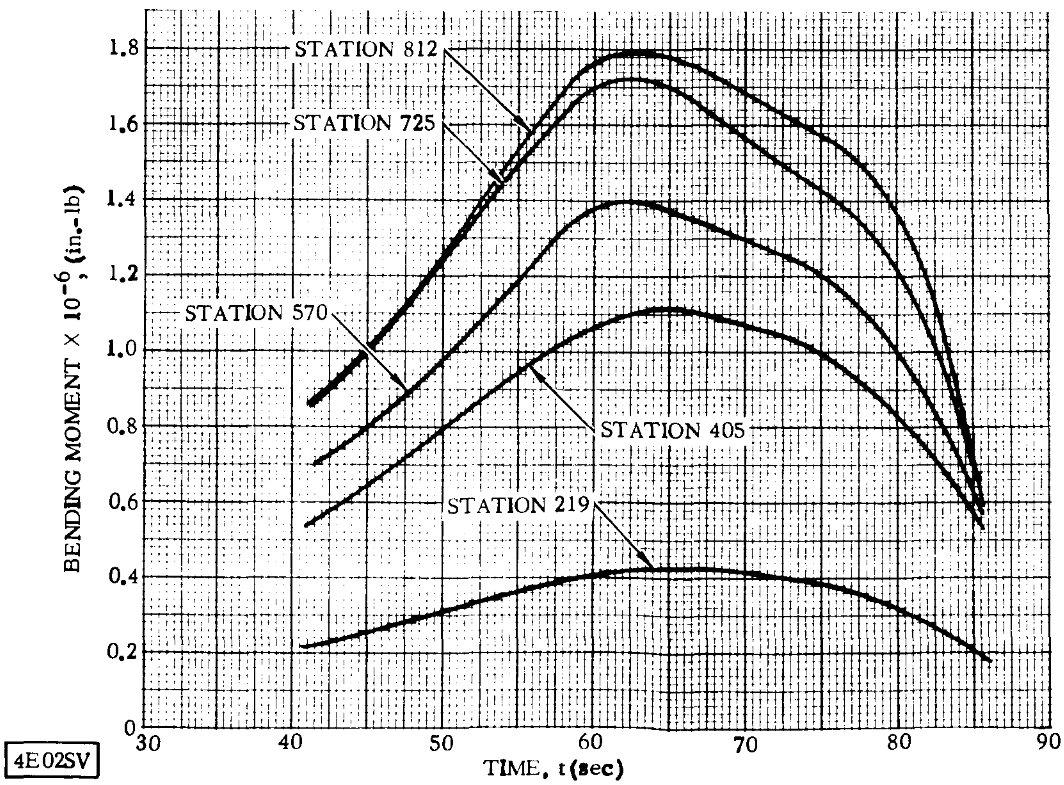


Figure 2-2. Bending Moment due to Gust in Yaw versus Time

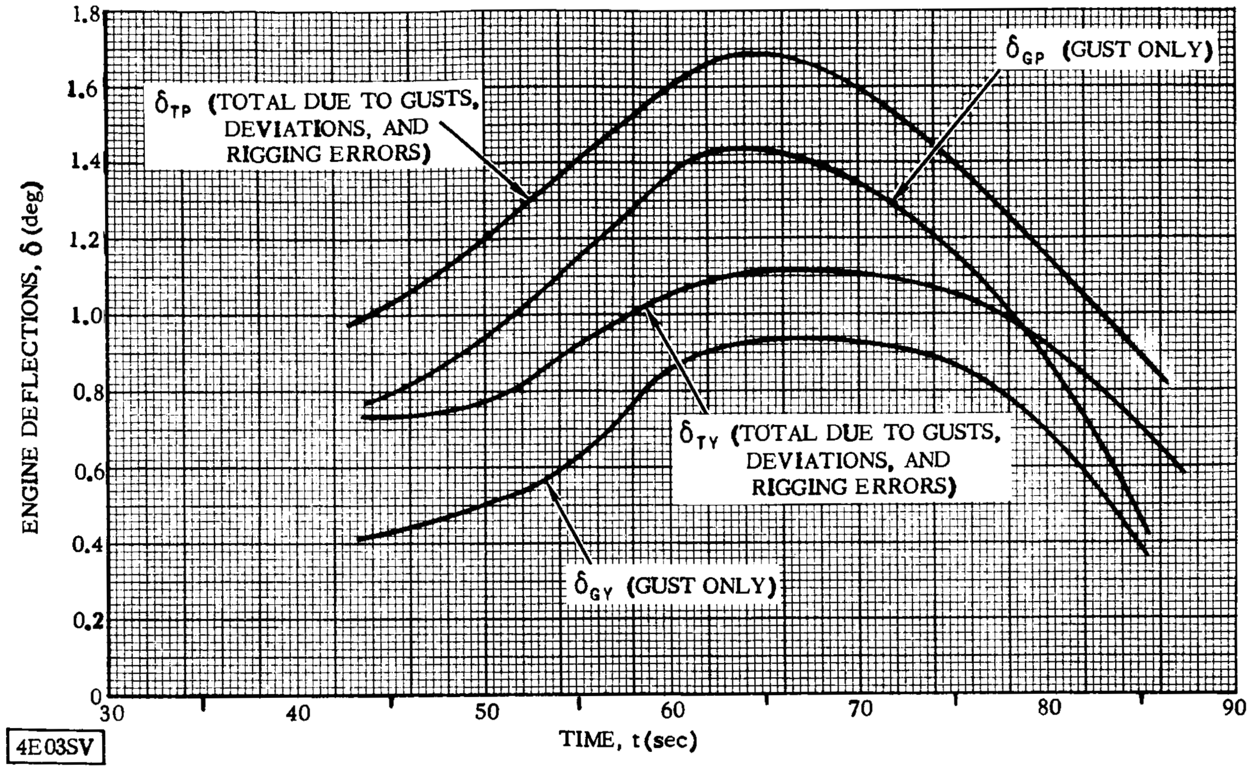


Figure 2-3. Engine Deflection due to Gust and Deviations versus Time

2.2 SOURCE OF BENDING MOMENT DUE TO DEVIATIONS

A 3-sigma deviation in bending moment due to dispersions in thrust, gross weight, specific impulse, etc. (Reference 2-4), has been used with the digital computer program found in Reference 2-5 to obtain the bending moment shown in Figure 2-4. This deviation is based on a study which utilized dispersions in eight independent variables affecting the vehicle trajectory. This bending moment increment will be used in deriving the Load Capability Ratio in Section III.

2.3 SOURCE OF BENDING MOMENT DUE TO PROPELLANT SLOSHING, ECCENTRICITY OF CENTER OF GRAVITY, AND TRANSONIC BUFFETING

2.3.1 PROPELLANT SLOSHING. All propellant-sloshing masses except the liquid hydrogen are naturally stable throughout the high-dynamic-pressure region which is critical for wind loads. The liquid-hydrogen slosh mass is so small as to have negligible effect on loads. Therefore, there will be no build-up of sloshing loads to add to the other loads. In the gust-loads program, the effect of propellant slosh response has been included. The program for computing loads due to the wind profile does not include sloshing degrees of freedom; but analog computer studies have shown that, for wind-profile inputs, sloshing has a negligible effect on gross bending moments (Reference 2-6).

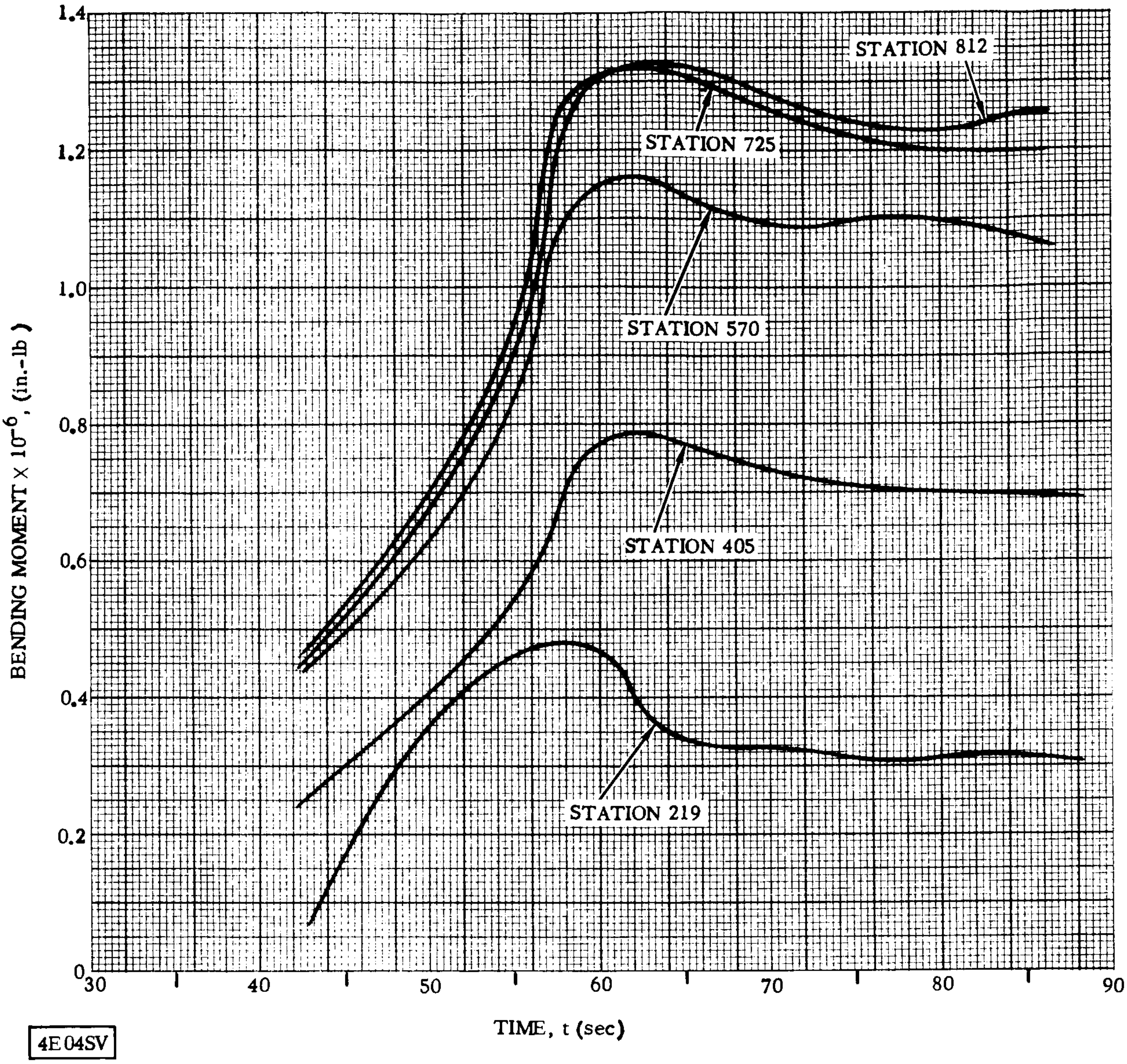


Figure 2-4. Bending Moment due to Deviations versus Time

2.3.2 ECCENTRICITY OF CENTER OF GRAVITY. Eccentricity (or lateral offset from the centerline) of the center of gravity is important only at booster-engine cutoff. Its effect, that of producing a small lateral acceleration, is included in the trajectory program used to calculate wind-profile bending moments.

2.3.3 TRANSONIC BUFFETING. Gross bending moments due to transonic buffeting have been considered for the entire vehicle and are generally negligible. They are used, however, at Station 219 between T = 48 and T = 64 seconds of flight. The bending moments plot given in Figure 2-4 has the bending moment due to transonic buffeting included for Station 219.

2.4 STATIC AEROELASTICITY

The COMBO program is a rigid-body simulation and therefore does not take into account the effects arising from the elasticity of the vehicle. Static aeroelastic factors (Figures 2-5 and 2-6) are obtained through the use of the digital program of Reference 2-7. The bending moments obtained from the bending moment program are multiplied by the aeroelastic factor Æ (Reference 2-8).

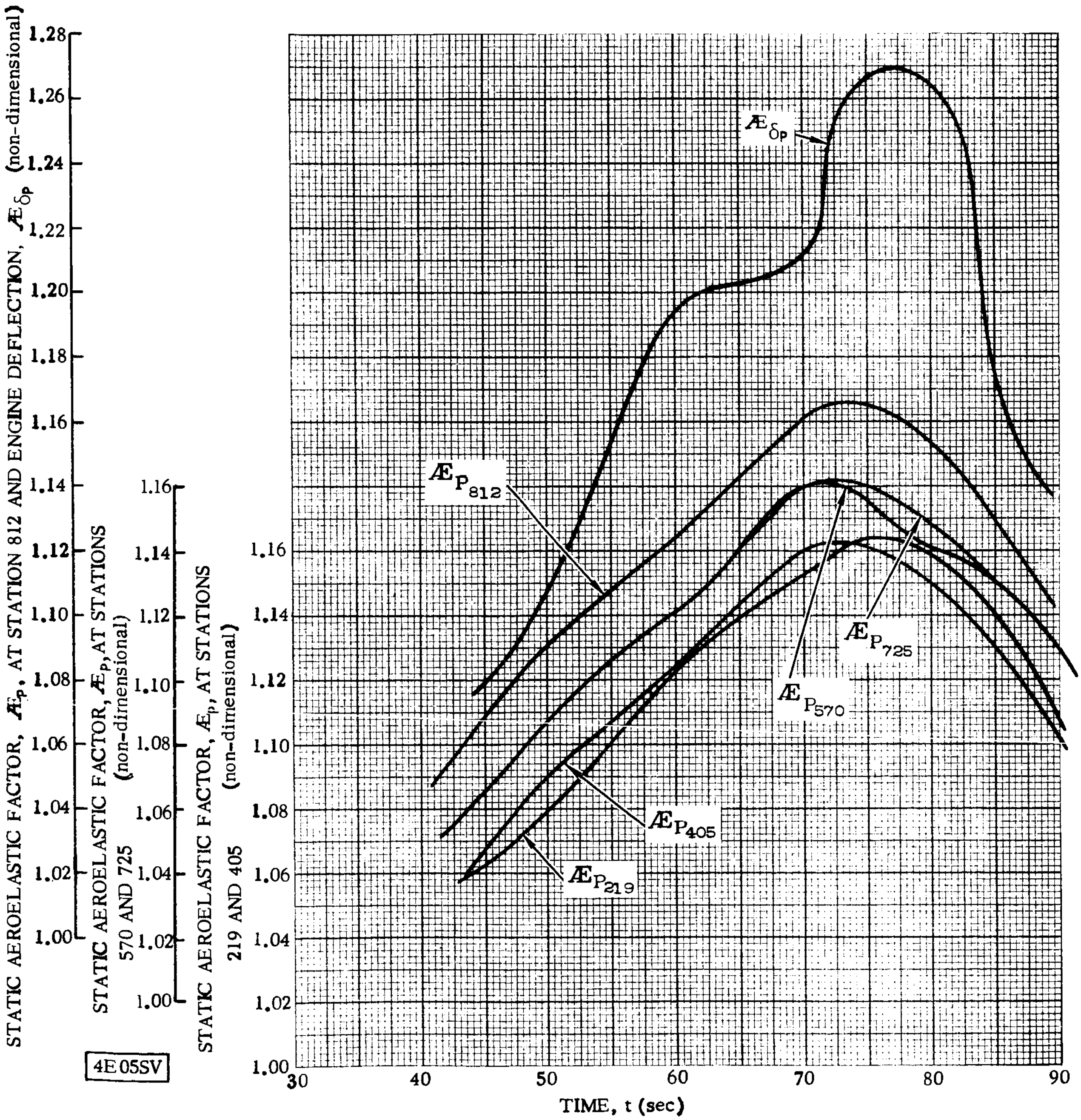


Figure 2-5. Steady-State Aeroelastic Effect on Engine Deflection and Bending Moment in the Pitch Plane

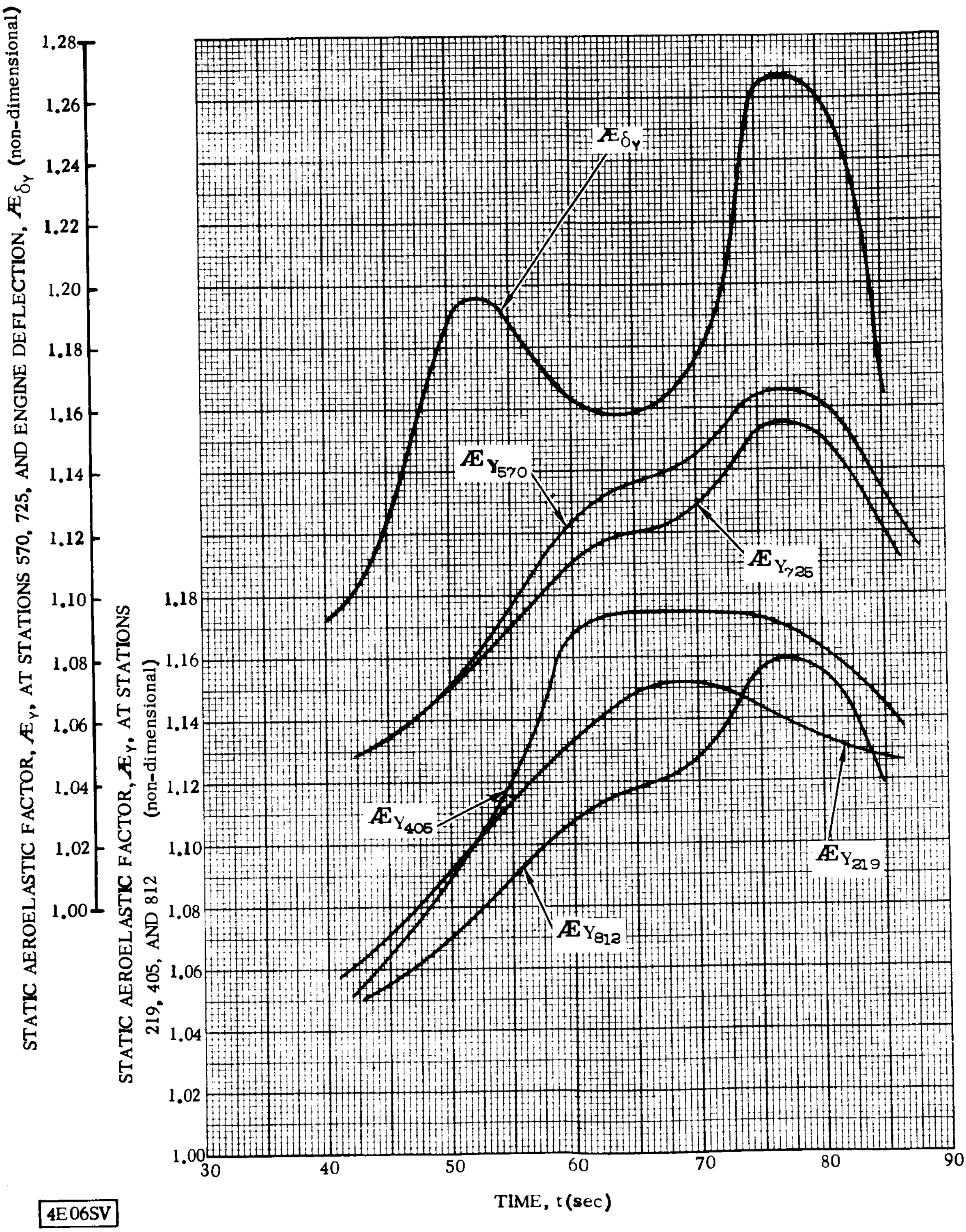


Figure 2-6. Steady-State Aeroelastic Effect on Engine Deflection and Bending Moment in the Yaw Plane

SECTION III

DETERMINATION OF LAUNCH AVAILABILITY

3.1 LOAD CAPABILITY RATIO AND ENGINE DEFLECTION RATIO

The launch availability of AC-6 to AC-15 due to winds aloft is dependent upon the Load Capability Ratio (LCR, Reference 3-1) and the Engine Deflection Ratio (EDR). The Load Capability Ratio is a modification of the stress design-ultimate interaction ratio:

$$LCR = \frac{M_{applied}(FS_m)}{M_{o_u}} + \frac{P_{applied}(FS_p)}{P_{o_u}}$$

where $M_{applied}$ and $P_{applied}$ are the calculated bending moments and axial loads, respectively. FS_m and FS_p are the respective factors of safety, and M_{o_u} and P_{o_u} the respective ultimate values. The M_{o_u} and P_{o_u} factors are listed in Table 3-1 and documented in References 3-2 through 3-5. The factor of safety, FS_m, equal to 1.25, and the factor of safety, FS_p, equal to 1.10 (for these launch availability calculations only) are as designated in Reference 2-3. $M_{applied}$ and $P_{applied}$ are calculated in the flight simulation, as is the Load Capability Ratio. The Engine Deflection Ratio is also calculated during the simulation.

3.2 SOURCE OF WIND PROFILES

3.2.1 WIND DATA REQUIREMENTS. Requirements for the wind data are given in Reference 3-6. Starting at F-2D (Firing minus 2 days), a forecast for planning purposes shall be made of general weather conditions which are expected to occur at T-0H (hours) in the flight area.

3.2.1.1 The F-2D forecast shall include:

a. Visibility
b. Temperature
c. Pressure
d. Cloud cover
e. Precipitation
f. Wind direction and velocity at 5,000-foot intervals from the surface to 50,000 feet
g. Identification of possible shears.

3.2.1.2 The F-1D forecast for operational purposes shall include:

a. Visibility

TABLE 3-1. ULTIMATE ALLOWABLE BENDING MOMENTS AND AXIAL LOADS

M_{o_u} = Ultimate bending moment at zero axial load (in.-lb)

Station	Bending Moment and Axial Load	Time, t(se					
		0	20	40	60	69	71
216	$M_{o_u} \times 10^{-6}$ P_{o_u}	0.9771 -36,225	0.9771 -36,225	0.9771 -36,225	0.9771 -36,225	0.9771 -36,225	0.9771 -36,225	0 -3
217	$M_{o_u} \times 10^{-6}$ P_{o_u}	4.3307 121,145	4.3307 121,145	4.3307 121,145	4.3307 121,145	4.3307 121,145	4.3307 121,145	4 12
219	$M_{o_u} \times 10^{-6}$ P_{o_u}	1.115 31,190	1.710 47,840	2.830 79,160	4.250 118,880	4.861 135,990	3.917 109,560	4 11
405	$M_{o_u} \times 10^{-6}$ P_{o_u}	1.602 53,430	2.457 81,960	4.066 135,620	6.105 203,660	6.984 232,980	5.627 187,700	5 19
413	$M_{o_u} \times 10^{-6}$ P_{o_u}	9.0497 301,890	9.0497 301,890	9.0497 301,890	9.0497 301,890	9.0497 301,890	9.0497 301,890	9 30
414	$M_{o_u} \times 10^{-6}$ P_{o_u}	1.3433 -44,810	1.3433 -44,810	1.3433 -44,810	1.3433 -44,810	1.3433 -44,810	1.3433 -44,810	1 -4
568	$M_{o_u} \times 10^{-6}$ P_{o_u}	10.460 349,000	10.460 349,000	10.460 349,000	10.460 349,000	10.460 349,000	10.460 349,000	10 34
667	$M_{o_u} \times 10^{-6}$ P_{o_u}	10.462 331,250	10.462 331,250	10.392 330,460	10.392 330,460	10.494 333,850	10.502 334,140	10 33
696	$M_{o_u} \times 10^{-6}$ P_{o_u}	10.580 332,590	10.580 332,590	10.580 332,590	10.500 331,690	10.602 335,080	10.610 335,370	10 34
725	$M_{o_u} \times 10^{-6}$ P_{o_u}	10.842 335,570	10.842 335,570	10.842 335,570	10.842 335,570	10.841 337,790	10.849 338,080	11 34
754	$M_{o_u} \times 10^{-6}$ P_{o_u}	10.986 337,200	10.986 337,200	10.986 337,200	10.986 337,200	11.088 340,590	11.096 340,880	11 34
784	$M_{o_u} \times 10^{-6}$ P_{o_u}	11.138 338,930	11.138 338,930	11.138 338,930	11.138 338,930	11.240 342,320	11.248 342610	11 34
812	$M_{o_u} \times 10^{-6}$ P_{o_u}	11.138 338,930	11.138 338,930	11.138 338,930	11.138 338,930	11.240 342,320	11.248 342,610	11 34
840	$M_{o_u} \times 10^{-6}$ P_{o_u}	11.138 338,930	11.138 338,930	11.138 338,930	11.138 338,930	11.240 342,320	11.248 342,610	11 34
871	$M_{o_u} \times 10^{-6}$ P_{o_u}	11.573 340,770	11.630 340,770	11.681 340,770	11.681 340,770	11.681 344,160	11.681 344,450	11 34

 1

P_{o_u} = Ultimate axial load at zero bending moment (lb)

:)						Characteristic
76	80	90	100	120	160	
.9771 6,225	0.9771 -36,225	0.9771 -36,225	0.9771 -36,225	0.9771 -36,225	0.9771 -36,225	Tension in the Station 219 ring
.3307 1,145	4.3307 121,145	4.3307 121,145	4.3307 121,145	4.3307 121,145	4.3307 121,145	Compression in the Station 219 ring
.087 4,320	4.212 117,820	4.403 123,170	4.502 125,950	4.547 127,200	4.488 125,550	Compression in the hydrogen tank skin at Station 219
.871 5,850	6.051 201,850	6.326 211,020	6.468 215,770	6.533 217,920	6.448 215,090	Compression in the hydrogen tank skin at Station 405
.0497 1,890	9.0497 301,890	9.0497 301,890	9.0497 301,890	9.0497 301,890	9.0497 301,890	Compression in the Station 408 ring
.3433 4,810	1.3433 -44,810	1.3433 -44,810	1.3433 -44,810	1.3433 -44,810	1.3433 -44,810	Tension in the Station 408 ring
.460 9,000	10.460 349,000	10.460 349,000	10.460 349,000	10.460 349,000	10.460 349,000	Compression at base of the interstage adapter
.667 9,620	10.724 341,540	10.775 343,240	10.775 343,240	10.775 343,240	10.775 343,240	Compression in Atlas LO_2 tank skin at Station 667
.775 0,850	10.832 342,775	10.883 344,470	10.883 344,470	10.883 344,470	10.883 344,470	Compression in Atlas LO_2 tank skin at Station 696
.014 3,560	11.071 345,485	11.122 345,485	11.122 345,485	11.122 345,485	11.122 345,485	Compression in Atlas LO_2 tank skin at Station 725
.261 5,360	11.202 346,985	11.253 348,680	11.253 348,680	11.253 348,680	11.253 348,680	Compression in Atlas LO_2 tank skin at Station 754
.413 8,090	11.470 350,015	11.521 351,710	11.392 350,260	11.392 350,260	11.392 350,260	Compression in Atlas LO_2 tank skin at Station 784
.413 8,090	11.470 350,015	11.521 351,710	11.521 351,710	11.392 350,260	11.392 350,260	Compression in Atlas LO_2 tank skin at Station 812
.413 8,090	11.470 350,015	11.521 351,710	11.521 351,710	11.392 350,260	11.392 350,260	Compression in Atlas LO_2 tank skin at Station 840
.298 9,930	11.298 351,850	11.298 353,550	11.298 353,550	11.400 353,550	11.408 353,550	Compression in Atlas LO_2 tank skin at Station 871

2 (2)

b. Temperature
c. Pressure
d. Cloud cover
e. Wind direction and velocity at 5,000-foot intervals from the surface to 50,000 feet
f. Identification of shear levels in altitude and magnitude which are greater than 5 knots per 1,000 feet
g. Identification of the maximum wind associated with each shear level.

3.2.1.3 If conditions warrant, an additional forecast may be issued by the Patrick Air Force Base 4th Weather Group at T-10H.

3.2.2 WEATHER OBSERVATIONS. Weather observations consist of wind speed in knots and azimuth in degrees from north. They are required at General Dynamics/Convair, San Diego, for wind-profile computer study and for assistance in a launch decision.

3.2.2.1 Weather balloons will be released by Eastern Test Range weather personnel at T-12H, T-7H, T-4H, T-2H, and approximately every hour thereafter until the vehicle is either launched or scrubbed. The observed data will be given at 1,000-foot intervals up to 50,000 feet with comments on trends and critical shears.

3.2.2.2 At T-0H a weather balloon will be released so that upper air soundings can be recorded. This data will be used for performance evaluation.

3.3 PROGRAM USED TO CALCULATE LOAD CAPABILITY AND ENGINE DEFLECTION RATIOS

A digital computer flight simulation, called the COMBO/Autopilot - Bending Moments/Axial Loads - Plotter Program, is in essence three independent programs coupled together. From this program, the Load Capability Ratios and Engine Deflection Ratios are determined.

3.3.1 COMBO PROGRAM. The COMBO Program (Reference 3-7) is a general trajectory program used in performance calculations of earth referenced space flights. The program is designed to simulate a rigid-body space vehicle flight from the surface of a rotating earth to altitudes of several hundred miles. The type of vehicle and the way in which it flies is not fixed in any way by the program construction. The primary purpose of the simulation of a ballistic missile flight is the analysis of the over-all trajectory information such as the time-histories of position, velocity, and acceleration.

The COMBO trajectory program computes the acceleration, velocity, and position along the trajectory of a vehicle. The basic element is the acceleration of the rigid vehicle. In the flight equations, the acceleration is extrapolated forward from point to point along the trajectory. After each extrapolation the acceleration is integrated twice to obtain a velocity and a position. A group of subroutines called FORCECODE uses the velocity and position to calculate an acceleration due to aerodynamic, wind, and thrust forces. The program corrects for center-of-gravity offsets and thrust misalignment. COMBO is programmed to function as a master program for use with and by other programs. Other programs may be completely independent, or dependent only for input values, such as the Autopilot Program or the Bending Moments Program.

3.3.2 AUTOPILOT PROGRAM. The Autopilot Program is a rigid-body simulation of the low-frequency response of the vehicle's attitude control system. A position gyro senses the reference attitude of the vehicle (θ) and a rate gyro senses the attitude rate change of the vehicle ($K_R \dot{\theta}$). These two quantities are summed to provide an attitude feedback (θ_F). This is subtracted from the command pitch attitude of the vehicle and results in an attitude error signal (θ_E). The attitude error signal is multiplied by the position-gyro gain factor (K_A) and also integrated with respect to time (K_I/S) to eliminate the buildup of an error resulting from a constant applied torque. These quantities are summed to yield a thrust-vector gimbaling command to the hydraulic actuator. The response of the thrust-chamber positioning servo is represented by first order lag and a control loop to stabilize the system. The autopilot program operates in both pitch and yaw planes.

3.3.3 BENDING MOMENTS/AXIAL LOADS PROGRAM. The bending moments and axial loads (due to wind profile) at various stations are computed through use of the Bending Moments/Axial Loads Program.

In computing the bending moments, the program uses various flight parameters, including lateral and rotational acceleration, angle of attack, and dynamic pressure, which are calculated in the COMBO and autopilot programs, and also input bending moment coefficients. The bending moments are computed in both the pitch and yaw planes, then root-sum-squared to obtain the total bending moment on the vehicle independent of the plane. The axial loadings at the various stations are computed by using the COMBO/autopilot outputs of axial acceleration and dynamic pressure, and input values of drag coefficients and weights.

3.4 SOURCES OF INPUT DATA FOR THE COMBO/AUTOPILOT PROGRAM

3.4.1 AUTOPILOT INPUT. Input data for the Autopilot Program was obtained from Reference 3-8 and consists of various autopilot gains.

3.4.2 INERTIA AND CENTER-OF-GRAVITY DATA. The inertia and center-of-gravity data was obtained from Reference 3-9. The center-of-gravity data includes all three axes.

3.4.3 PITCH PROGRAM AND INITIAL WEIGHT. The pitch program and vehicle initial weight were obtained from Reference 3-10. The referenced document is a monthly report, and therefore if any weight changes occur from month to month, the latest weight value will be inserted into the program.

3.4.4 THRUST AND PROPELLANT FLOW. The thrust for the booster engines and sustainer engine, and the total propellant flow was obtained from Reference 3-11.

3.4.5 AERODYNAMIC DATA. Normal and side force coefficients, along with their corresponding centers of pressure, as functions of Mach number were taken from Reference 3-12. The angle of attack for these coefficients varied between -5 degrees and +5 degrees, with a range of Mach numbers from 0 to 1.96.

3.5 SOURCES OF INPUT DATA FOR THE BENDING MOMENTS/AXIAL LOADS PROGRAM

3.5.1 BENDING MOMENT COEFFICIENTS. To calculate the bending moments due to the flight-wind profile, two sets of bending moment coefficients are required. One set is for calculating the inertial bending moments, the other set for calculating aerodynamic bending moments.

3.5.1.1 The inertial coefficients were obtained by using a separate digital program (Reference 3-13). The program calculates the coefficients due to lateral and rotational accelerations of the vehicle using structural and propellant weight distributions as input.

3.5.1.2 The aerodynamic bending moment coefficients were obtained from Reference 3-12.

3.5.2 ADDITIONAL BENDING MOMENTS. In addition to the calculated bending moments using the above data, the bending moments called out in Section II are used to obtain the total calculated bending moments.

3.6 CALCULATED ENGINE DEFLECTION

The engine deflection due to wind profile is obtained from the autopilot output. Factors for thrust misalignment and rigging errors, along with gust and deviation angles, are root-sum-squared and added to the wind-profile deflection. In addition, a static aeroelastic factor is used on the deflection contributed by the flight-wind profile.

SECTION IV

PRESENTATION OF WIND-RESTRICTION PROCEDURE RESULTS

4.1 DISPLAY OF RESULTS FROM DIGITAL PROGRAM AT SAN DIEGO

4.1.1 SC4020 MICROFILM RECORDER. The Stromberg-Carlson 4020 High Speed Microfilm Recorder records digital information from a magnetic tape produced by the IBM 7094 computer and transfers it to a 16-mm film or to a nine-inch photo-recording paper. There are two automatic electronically controlled cameras in the SC 4020 recorder. The microfilm recorder takes sequential exposures of preselected grid structures, ordinates, labels, alpha-numeric characters, and plotted curves from projections on an S. C. Charactron tube. A time-cycle of approximately one second is required to produce each 16-mm frame. The nine-inch camera requires approximately two seconds for each frame. The recording paper from the nine-inch camera is developed internally within the two-second cycle and ejected automatically. Film from the 16-mm camera is developed by conventional procedures external to the SC 4020 and is used for making permanent hard copy such as reproducible vellum prints. The SC4020 at General Dynamics/ Convair (GD/C) is one of two such recorders currently in use which feature the two-second viewing cycle.

4.1.2 PREPROGRAMMED SC 4020 INPUT. The IBM 7094 prepares the tape to be used on the SC 4020. The grids, scales, and individual plot titles are fixed and do not vary between runs. Also the engine deflection limits are fixed.

4.1.3 SC 4020 LAUNCH RECOMMENDATION OUTPUT. Three curves appear on each load capability plot. The top curve represents a plot of the sum of the calculated (applied) bending moments and axial loads times their respective factors of safety and divided by their respective ultimate values. This value is the Load Capability Ratio. If this value exceeds unity, the structural integrity of the vehicle would be jeopardized were a launch attempted.

The bottom curve (dotted) is equivalent to the upper curve, except that the gust and deviations bending moments have been removed from the calculated bending moment. The middle curve is also the same as the upper curve, but with the factors of safety removed. This is the Structural Capability Ratio (Reference 3-1).

4.1.4 SC 4020 ENGINE-ANGLE OUTPUT. Four curves appear on both engine-angle plots. The engine-angle limits (±5 degrees) are horizontal straight lines above and below the engine-angle grids. These values are fixed and do not vary between runs. The solid curve is the deflection due to the product of wind profile times the aeroelastic factor.

The dotted line represents the solid line plus the root-sum-square of the 30-foot-per-second gust, rigging, thrust misalignment, and deviations. It is the total calculated engine deflection at a particular time in flight. If the deflection exceeds the limits, there is danger that the vehicle will tumble.

4.1.5 SC 4020 ANGLE-OF-ATTACK AND ANGLE-OF-ATTACK TIMES DYNAMIC PRESSURE PLOTS. The angle of attack plots (alpha and beta) and angle of attack times dynamic pressure also include gust values. The solid lines represent values due to wind profile, pitch program, etc., and the dotted line is the preceding value with an angle-of-attack due to gust added.

4.2 FORMAT FOR WIND-RESTRICTION DATA SENT TO THE EASTERN TEST RANGE

4.2.1 IMMEDIATE TRANSMISSION. The results derived from the foregoing display are telephoned immediately and confirmed by TWX to the Eastern Test Range (ETR). They are transmitted as:

a. The maximum value of the Load Capability Ratio for each station
b. The maximum value of the Structural Capability Ratio
c. The ratio of the maximum calculated engine-deflection angle, due to the wind profile and gust, to the design-limit engine-deflection angle, $\delta_{CALC}/\delta_{DL}$, in either the pitch or yaw plane.
d. Recommendation of GO or NO GO per Table 5-2.

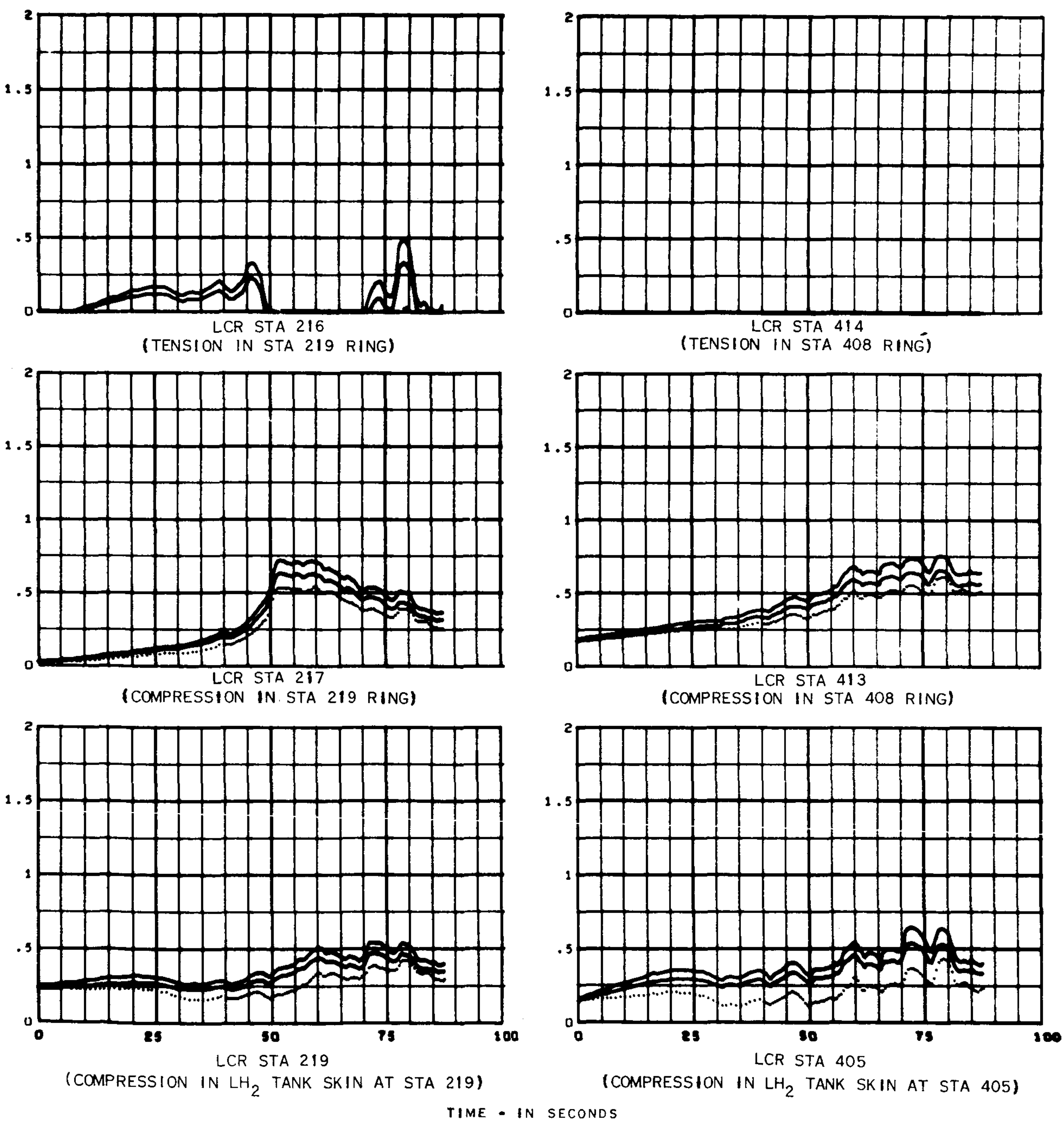
4.2.2 FOLLOW-ON REPORT. Subsequently, reproductions of the wind-profile data originally displayed on the SC 4020, at T-0H, are mailed to GD/C at ETR as part of a report.

4.2.3 SC4020 DISPLAY. An example of the SC4020 film output is shown in Figures 4-1 through 4-6 and Tables 4-1 through 4-12. The ETR wind profile for 6 July 1961 was inserted into the AC-6 COMBO/Autopilot - Bending Moments/Axial Loads - Plotter Program to generate these results.

Tables 4-1 through 4-12 present digital print-outs of the plots of Figures 4-1 and 4-2 plus the calculated bending moments and axial loads due to the wind profile. Thus critical times can be observed in Figures 4-1 and 4-2 and printed results scanned and recorded for transmission to ETR Complex 36 in less than one minute of elapsed time after the SC 4020 begins the display. The display begins within two minutes after the tape from the IBM 7094 is placed on the SC 4020. Figures 4-3 through 4-6 show plots of engine deflections plus various other flight parameters.

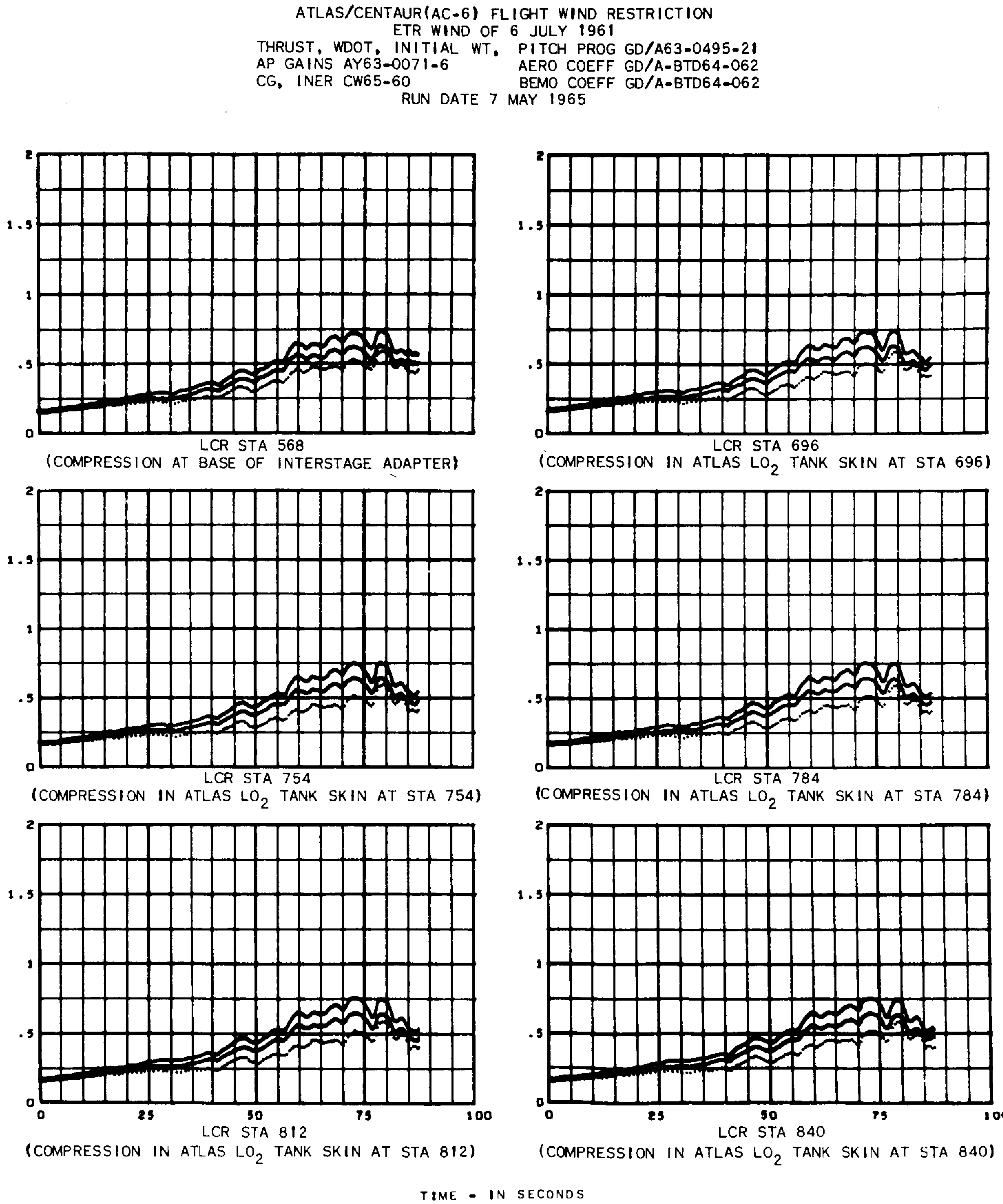
ATLAS/CENTAUR (AC-6) FLIGHT WIND RESTRICTION
ETR WIND OF 6 JULY 1961

THRUST, WDOT, INITIAL WT, PITCH PROG GD/A63-0495-21
AP GAINS AY63-0071-6 AERO COEFF GD/A-BTD64-062
CG, INER CW65-60 BEMO COEFF GD/A-BTD64-062
RUN DATE 7 MAY 1965



4E07SV

Figure 4-1. Wind Restriction for Load Capability (Stations 216 through 405)



4E08SV

Figure 4-2. Wind Restriction for Load Capability
(Stations 568 through 840)

TABLE 4-1. STRUCTURAL CAPABILITY RATIO AT STATION 217 VERSUS TIME

TIME	217 SCR		ETR WIND OF 6 JULY 1961		
0.00	0.02238409	51.00	0.60089307	82.50	0.33828640
0.03	0.02239927	51.50	0.62580976	83.00	0.33789092
1.00	0.02388786	52.00	0.62997254	83.50	0.33940351
2.00	0.02563726	52.50	0.62803695	84.00	0.33496953
3.00	0.02783630	53.00	0.62258726	84.50	0.32600524
4.00	0.03021217	53.50	0.61721564	85.00	0.32800112
5.00	0.03268277	54.00	0.61340400	85.50	0.32473425
6.00	0.03526681	54.50	0.61002048	86.00	0.30992796
7.00	0.03795441	55.00	0.61725180	86.50	0.31619600
8.00	0.04074509	55.50	0.62459231	87.00	0.31783409
9.00	0.04364265	56.00	0.62161156	87.36	0.31975448
10.00	0.04665064	56.50	0.61267105		
11.00	0.04977431	57.00	0.60136636		
12.00	0.05301773	57.50	0.61140685		
13.00	0.05638535	58.00	0.61796428		
14.00	0.05988366	58.50	0.62020541		
15.00	0.06378163	59.00	0.62719406		
16.00	0.06785778	59.50	0.62349801		
17.00	0.07077246	60.00	0.61873995		
18.00	0.07496483	60.50	0.61263037		
19.00	0.07956451	61.00	0.60791172		
20.00	0.08429329	61.50	0.57929053		
21.00	0.08807378	62.00	0.57783388		
22.00	0.09219534	62.50	0.58201267		
23.00	0.09665857	63.00	0.58061226		
24.00	0.10116867	63.50	0.57350510		
25.00	0.10477585	64.00	0.56447510		
26.00	0.10850864	64.50	0.55419430		
27.00	0.11235425	65.00	0.53966106		
28.00	0.11427270	65.50	0.52380652		
29.00	0.11580198	66.00	0.51622134		
30.00	0.11742437	66.50	0.53038473		
31.00	0.11992673	67.00	0.52657522		
32.00	0.13017207	67.50	0.51314005		
33.00	0.13816102	68.00	0.50621547		
34.00	0.14249311	68.50	0.49409484		
35.00	0.14894693	69.00	0.47391762		
36.00	0.15938596	69.50	0.45705575		
37.00	0.16939470	70.00	0.44665457		
38.00	0.18012724	70.50	0.45361401		
39.00	0.18923642	71.00	0.46470059		
40.00	0.19021398	71.50	0.46567456		
40.50	0.19021079	72.00	0.46548431		
41.00	0.18870968	72.50	0.46345546		
41.50	0.18994181	73.00	0.45959754		
42.00	0.19635386	73.50	0.45458858		
42.50	0.20489320	74.00	0.44696843		
43.00	0.21294503	74.50	0.43004758		
43.50	0.22058016	75.00	0.41296355		
44.00	0.22834097	75.50	0.40160278		
44.50	0.24145425	76.00	0.39037310		
45.00	0.25521943	76.50	0.38860049		
45.50	0.26837740	77.00	0.40282879		
46.00	0.28524036	77.50	0.42074469		
46.50	0.30581300	78.00	0.43440675		
47.00	0.32540990	78.50	0.43507109		
47.50	0.34258358	79.00	0.43089258		
48.00	0.35988590	79.50	0.42653388		
48.50	0.37524096	80.00	0.42012031		
49.00	0.38900646	80.50	0.40633717		
49.50	0.41995603	81.00	0.38416147		
50.00	0.47566843	81.50	0.35704136		
50.50	0.53967339	82.00	0.34490558		

TABLE 4-2. STRUCTURAL CAPABILITY RATIO AT STATION 413 VERSUS TIME

TIME	413 SCR		ETR WIND OF 6 JULY 1961		
0.00	0.16677908	51.00	0.42262490	82.50	0.54782366
0.03	0.16684382	51.50	0.42824688	83.00	0.55096501
1.00	0.17115490	52.00	0.43060316	83.50	0.55676132
2.00	0.17337233	52.50	0.43324646	84.00	0.55575882
3.00	0.17663488	53.00	0.43709163	84.50	0.55600456
4.00	0.18013229	53.50	0.44265153	85.00	0.57663103
5.00	0.18360516	54.00	0.44806343	85.50	0.56732200
6.00	0.18719198	54.50	0.45333692	86.00	0.56562370
7.00	0.19085118	55.00	0.45588331	86.50	0.56105588
8.00	0.19457453	55.50	0.47931661	87.00	0.55457546
9.00	0.19836608	56.00	0.47506465	87.36	0.56358355
10.00	0.20222584	56.50	0.48633434		
11.00	0.20615529	57.00	0.50169392		
12.00	0.21015522	57.50	0.53355593		
13.00	0.21422471	58.00	0.55151614		
14.00	0.21836836	58.50	0.56204053		
15.00	0.22287329	59.00	0.57671566		
16.00	0.22912782	59.50	0.58690347		
17.00	0.23016394	60.00	0.59140403		
18.00	0.23523880	60.50	0.58534932		
19.00	0.24022644	61.00	0.57067679		
20.00	0.24525994	61.50	0.57406650		
21.00	0.24895885	62.00	0.54654941		
22.00	0.25300162	62.50	0.56308686		
23.00	0.25740347	63.00	0.56992992		
24.00	0.26183497	63.50	0.57030960		
25.00	0.26523133	64.00	0.56828240		
26.00	0.26878603	64.50	0.56468450		
27.00	0.27249128	65.00	0.55527820		
28.00	0.27332906	65.50	0.55449517		
29.00	0.27330791	66.00	0.58801078		
30.00	0.27333842	66.50	0.60312615		
31.00	0.27403487	67.00	0.60770388		
32.00	0.28689755	67.50	0.60907978		
33.00	0.29265600	68.00	0.61470472		
34.00	0.29311255	68.50	0.61490619		
35.00	0.29863504	69.00	0.60430629		
36.00	0.31034285	69.50	0.59513760		
37.00	0.32031525	70.00	0.59075097		
38.00	0.33011532	70.50	0.60412385		
39.00	0.33803683	71.00	0.62277712		
40.00	0.33607695	71.50	0.63212067		
40.50	0.33503803	72.00	0.63772456		
41.00	0.32954477	72.50	0.64036938		
41.50	0.32792500	73.00	0.63866703		
42.00	0.33693667	73.50	0.63577175		
42.50	0.34714731	74.00	0.63314633		
43.00	0.35526088	74.50	0.62017335		
43.50	0.36244819	75.00	0.60357751		
44.00	0.36942585	75.50	0.58905322		
44.50	0.37853435	76.00	0.56724875		
45.00	0.38861732	76.50	0.55922278		
45.50	0.39811918	77.00	0.59088336		
46.00	0.40382690	77.50	0.62270166		
46.50	0.40849493	78.00	0.64782013		
47.00	0.41123369	78.50	0.65552197		
47.50	0.40999304	79.00	0.65473694		
48.00	0.40794162	79.50	0.64995386		
48.50	0.40332714	80.00	0.64343184		
49.00	0.39745896	80.50	0.62892230		
49.50	0.39714195	81.00	0.60473311		
50.00	0.38989478	81.50	0.57194897		
50.50	0.40998128	82.00	0.55514171		

TABLE 4-3. STRUCTURAL CAPABILITY RATIO AT STATION 812 VERSUS TIME

TIME	812 SCR		ETR WIND OF 6 JULY 1961		
0.00	0.16448898	51.00	0.38844177	82.50	0.51040668
0.50	0.16452197	51.50	0.39821734	83.00	0.52739131
1.00	0.15803313	52.00	0.40884006	83.50	0.53436455
2.00	0.16351014	52.50	0.41757885	84.00	0.52135500
3.00	0.16577258	53.00	0.42919107	84.50	0.49360418
4.00	0.16749280	53.50	0.43938843	85.00	0.47037439
5.00	0.16993159	54.00	0.44871839	85.50	0.46008478
6.00	0.17367140	54.50	0.45273842	86.00	0.45873187
7.00	0.17782451	55.00	0.45320262	86.50	0.45700518
8.00	0.18167613	55.50	0.45169228	87.00	0.44655268
9.00	0.18558425	56.00	0.45086198	87.36	0.47473644
10.00	0.18957618	56.50	0.45274193		
11.00	0.19364060	57.00	0.46976464		
12.00	0.19776758	57.50	0.49753828		
13.00	0.20194524	58.00	0.51940002		
14.00	0.20617664	58.50	0.53024762		
15.00	0.21073718	59.00	0.54397882		
16.00	0.22407174	59.50	0.56198650		
17.00	0.21632878	60.00	0.54608957		
18.00	0.22296938	60.50	0.55620996		
19.00	0.22814756	61.00	0.54257792		
20.00	0.23341807	61.50	0.53595843		
21.00	0.23738109	62.00	0.53712138		
22.00	0.24192876	62.50	0.54828039		
23.00	0.24700058	63.00	0.55848678		
24.00	0.25226452	63.50	0.55939368		
25.00	0.25667262	64.00	0.55705105		
26.00	0.26140045	64.50	0.55458422		
27.00	0.26632861	65.00	0.55184912		
28.00	0.26692684	65.50	0.55280935		
29.00	0.26586847	66.00	0.55742761		
30.00	0.26657327	66.50	0.57369931		
31.00	0.26530086	67.00	0.58946480		
32.00	0.26527223	67.50	0.59588412		
33.00	0.27560215	68.00	0.60142761		
34.00	0.27873060	68.50	0.60479341		
35.00	0.28377087	69.00	0.59479522		
36.00	0.28750773	69.50	0.58176528		
37.00	0.29592422	70.00	0.57717267		
38.00	0.30648243	70.50	0.59267248		
39.00	0.31505767	71.00	0.61888776		
40.00	0.31012712	71.50	0.63475351		
40.50	0.30996222	72.00	0.64094648		
41.00	0.30335405	72.50	0.64689445		
41.50	0.31569833	73.00	0.64625834		
42.00	0.32800766	73.50	0.64316376		
42.50	0.33813979	74.00	0.64006813		
43.00	0.34571211	74.50	0.62725772		
43.50	0.35231908	75.00	0.60797851		
44.00	0.35886340	75.50	0.59370425		
44.50	0.36805353	76.00	0.57265060		
45.00	0.37894441	76.50	0.53752326		
45.50	0.38993369	77.00	0.53851282		
46.00	0.39590519	77.50	0.57929531		
46.50	0.39985058	78.00	0.61895484		
47.00	0.40212450	78.50	0.63653031		
47.50	0.39941131	79.00	0.63966466		
48.00	0.39491642	79.50	0.63445263		
48.50	0.38888973	80.00	0.62488843		
49.00	0.38093725	80.50	0.60166098		
49.50	0.37823616	81.00	0.56594600		
50.00	0.37734553	81.50	0.52185961		
50.50	0.37834445	82.00	0.51099231		

TABLE 4-4. LOAD CAPABILITY RATIO AT STATION 217 VERSUS TIME

TIME	217 LCR		ETR	WIND OF	8 JULY 1961
0.00	0.02488483	51.00	0.68394700	82.50	0.38031898
0.03	0.02490330	51.50	0.71229063	83.00	0.38807425
1.00	0.02674464	52.00	0.71740928	83.50	0.39017428
2.00	0.02890327	52.50	0.71495429	84.00	0.38484891
3.00	0.03161507	53.00	0.70819193	84.50	0.37394818
4.00	0.03453846	53.50	0.70159801	85.00	0.37683609
5.00	0.03757023	54.00	0.69703553	85.50	0.37318292
6.00	0.04073309	54.50	0.69307441	86.00	0.35508103
7.00	0.04401400	55.00	0.70209857	86.50	0.36328273
8.00	0.04741169	55.50	0.71126519	87.00	0.36567025
9.00	0.05093026	56.00	0.70763275	87.36	0.36031379
10.00	0.05457340	56.50	0.69661511		
11.00	0.05834692	57.00	0.68274335		
12.00	0.06225521	57.50	0.69563814		
13.00	0.06630312	58.00	0.70405503		
14.00	0.07049794	58.50	0.70695503		
15.00	0.07517471	59.00	0.71589867		
16.00	0.08005610	59.50	0.71146941		
17.00	0.08346351	60.00	0.70568657		
18.00	0.08844727	60.50	0.69840506		
19.00	0.09391824	61.00	0.69285744		
20.00	0.09952854	61.50	0.65763579		
21.00	0.10393684	62.00	0.65643726		
22.00	0.10874893	62.50	0.66234680		
23.00	0.11396467	63.00	0.66135825		
24.00	0.11921577	63.50	0.65331566		
25.00	0.12331561	64.00	0.64291504		
26.00	0.12754775	64.50	0.63101431		
27.00	0.13189575	65.00	0.61386838		
28.00	0.13380336	65.50	0.59511164		
29.00	0.13519657	66.00	0.58676775		
30.00	0.13667920	66.50	0.60568066		
31.00	0.13923015	67.00	0.60218421		
32.00	0.15143383	67.50	0.58671469		
33.00	0.16078991	68.00	0.57944320		
34.00	0.16554723	68.50	0.56573181		
35.00	0.17292574	69.00	0.54202831		
36.00	0.18524877	69.50	0.52253248		
37.00	0.19700395	70.00	0.51058790		
38.00	0.20962989	70.50	0.51990521		
39.00	0.22020533	71.00	0.53438998		
40.00	0.22061574	71.50	0.53623455		
40.50	0.22019697	72.00	0.53665503		
41.00	0.21790390	72.50	0.53480193		
41.50	0.21902402	73.00	0.53069335		
42.00	0.22655271	73.50	0.52518410		
42.50	0.23668855	74.00	0.51646166		
43.00	0.24620022	74.50	0.49611050		
43.50	0.25517430	75.00	0.47558724		
44.00	0.26429471	75.50	0.46225506		
44.50	0.28010050	76.00	0.44887158		
45.00	0.29671084	76.50	0.44711303		
45.50	0.31254858	77.00	0.46533067		
46.00	0.33197946	77.50	0.48822626		
46.50	0.35538446	78.00	0.50585168		
47.00	0.37741895	78.50	0.50729646		
47.50	0.39623145	79.00	0.50268199		
48.00	0.41507623	79.50	0.49734706		
48.50	0.43128150	80.00	0.48942083		
49.00	0.44534610	80.50	0.47230513		
49.50	0.47850474	81.00	0.44484713		
50.00	0.54158876	81.50	0.41127265		
50.50	0.61462637	82.00	0.39633133		

TABLE 4-5. LOAD CAPABILITY RATIO AT STATION 413 VERSUS TIME

TIME	413 LCR		ETR WIND OF 6 JULY 1961		
0.00	0.18351293	51.00	0.48250243	82.50	0.62149900
0.03	0.18358981	51.50	0.48891441	83.00	0.62526803
1.00	0.18885092	52.00	0.49121760	83.50	0.63233185
2.00	0.19148554	52.50	0.49388529	84.00	0.63090308
3.00	0.19542115	53.00	0.49800716	84.50	0.63108554
4.00	0.19964453	53.50	0.50427986	85.00	0.65678703
5.00	0.20383177	54.00	0.51035401	85.50	0.64508547
6.00	0.20815527	54.50	0.51623898	86.00	0.64287131
7.00	0.21256274	55.00	0.51842763	86.50	0.63705808
8.00	0.21704373	55.50	0.54666923	87.00	0.62884878
9.00	0.22160317	56.00	0.54031150	87.36	0.64001855
10.00	0.22624052	56.50	0.55334780		
11.00	0.23095738	57.00	0.57176618		
12.00	0.23575441	57.50	0.61032850		
13.00	0.24063040	58.00	0.63188559		
14.00	0.24559056	58.50	0.64435388		
15.00	0.25099328	59.00	0.66206650		
16.00	0.25857391	59.50	0.67408738		
17.00	0.25959981	60.00	0.67886047		
18.00	0.26566218	60.50	0.67057601		
19.00	0.27160279	61.00	0.65164125		
20.00	0.27758775	61.50	0.65578188		
21.00	0.28192233	62.00	0.62130698		
22.00	0.28667556	62.50	0.64189922		
23.00	0.29186600	63.00	0.65038078		
24.00	0.29708182	63.50	0.65080380		
25.00	0.30099387	64.00	0.64822043		
26.00	0.30509154	64.50	0.64369358		
27.00	0.30936488	65.00	0.63192908		
28.00	0.31003924	65.50	0.63095200		
29.00	0.30962851	66.00	0.67287185		
30.00	0.30926898	66.50	0.69180585		
31.00	0.30972687	67.00	0.69757266		
32.00	0.32537923	67.50	0.69934698		
33.00	0.33214039	68.00	0.70645484		
34.00	0.33226022	68.50	0.70679073		
35.00	0.33869761	69.00	0.69361881		
36.00	0.35284971	69.50	0.68226501		
37.00	0.36482166	70.00	0.67680792		
38.00	0.37656184	70.50	0.69349195		
39.00	0.38594119	71.00	0.71676795		
40.00	0.38296210	71.50	0.72839458		
40.50	0.38139636	72.00	0.73535723		
41.00	0.37426043	72.50	0.73863384		
41.50	0.37196375	73.00	0.73648725		
42.00	0.38293316	73.50	0.73286372		
42.50	0.39538299	74.00	0.72959656		
43.00	0.40520517	74.50	0.71337778		
43.50	0.41386250	75.00	0.69264038		
44.00	0.42225517	75.50	0.67450801		
44.50	0.43351161	76.00	0.64722601		
45.00	0.44558137	76.50	0.63713281		
45.50	0.45711891	77.00	0.67662869		
46.00	0.46387296	77.50	0.71635451		
46.50	0.46930398	78.00	0.74772648		
47.00	0.47231014	78.50	0.75735828		
47.50	0.47032426	79.00	0.75637450		
48.00	0.46732181	79.50	0.75016812		
48.50	0.46110523	80.00	0.74178481		
49.00	0.45331136	80.50	0.72343586		
49.50	0.45238818	81.00	0.69305923		
50.00	0.44276543	81.50	0.65196766		
50.50	0.46728921	82.00	0.63079516		

TABLE 4-6. LOAD CAPABILITY RATIO AT STATION 812 VERSUS TIME

TIME	812 LCR		ETR WIND OF 6 JULY 1961		
0.00	0.18242109	51.00	0.44843910	82.50	0.59817997
0.03	0.18245858	51.50	0.46026361	83.00	0.60722841
1.00	0.17422966	52.00	0.47062131	83.50	0.61574407
2.00	0.18095103	52.50	0.48361685	84.00	0.59928730
3.00	0.18365103	53.00	0.49769656	84.50	0.58443503
4.00	0.18566985	53.50	0.50999557	85.00	0.53525783
5.00	0.18858393	54.00	0.51870486	85.50	0.52226424
6.00	0.19312082	54.50	0.52576281	86.00	0.52042575
7.00	0.19817066	55.00	0.52576913	86.50	0.51811254
8.00	0.20284001	55.50	0.52328340	87.00	0.50488853
9.00	0.20757630	56.00	0.52164920	87.36	0.53999617
10.00	0.21241336	56.50	0.52339965		
11.00	0.21733694	57.00	0.54408591		
12.00	0.22233447	57.50	0.57821684		
13.00	0.22739119	58.00	0.60499250		
14.00	0.23251055	58.50	0.61807326		
15.00	0.23803662	59.00	0.63478510		
16.00	0.25452552	59.50	0.65678600		
17.00	0.24464205	60.00	0.63630248		
18.00	0.25273115	60.50	0.64844270		
19.00	0.25898486	61.00	0.63098115		
20.00	0.26534637	61.50	0.62260928		
21.00	0.27009419	62.00	0.62397348		
22.00	0.27556703	62.50	0.63782178		
23.00	0.28168897	63.00	0.65047617		
24.00	0.28804488	63.50	0.65151455		
25.00	0.29332640	64.00	0.64848740		
26.00	0.29900107	64.50	0.64531518		
27.00	0.30491951	65.00	0.64181716		
28.00	0.30541825	65.50	0.64294094		
29.00	0.30384117	66.00	0.64864700		
30.00	0.30446089	66.50	0.66892419		
31.00	0.30260138	67.00	0.68856882		
32.00	0.30228919	67.50	0.69653363		
33.00	0.31492031	68.00	0.70341316		
34.00	0.31854186	68.50	0.70757426		
35.00	0.32454530	69.00	0.69502123		
36.00	0.32891080	69.50	0.67867481		
37.00	0.33912141	70.00	0.67282938		
38.00	0.35200033	70.50	0.69206760		
39.00	0.36239244	71.00	0.72469086		
40.00	0.35589545	71.50	0.74443423		
40.50	0.35552178	72.00	0.75209076		
41.00	0.34709208	72.50	0.75944845		
41.50	0.36235101	73.00	0.75858032		
42.00	0.37755232	73.50	0.75464515		
42.50	0.39002150	74.00	0.75071650		
43.00	0.39928713	74.50	0.73463016		
43.50	0.40734207	75.00	0.71046101		
44.00	0.41531758	75.50	0.69255532		
44.50	0.42660092	76.00	0.66614641		
45.00	0.44000695	76.50	0.62208336		
45.50	0.45353230	77.00	0.62314968		
46.00	0.46076055	77.50	0.67397673		
46.50	0.46544019	78.00	0.72341156		
47.00	0.46802299	78.50	0.74526047		
47.50	0.46436252	79.00	0.74905475		
48.00	0.45847442	79.50	0.74233805		
48.50	0.45066923	80.00	0.73018251		
49.00	0.44045031	80.50	0.70093850		
49.50	0.43675106	81.00	0.65812411		
50.00	0.43529160	81.50	0.60086029		
50.50	0.43618200	82.00	0.58709025		

TABLE 4-7. MOMENT APPLIED AT STATION 217 VERSUS TIME

TIME 217 M AP (IN-LBS X -06) ETR WIND OF 6 JULY 1961

0.00	0.00757383	51.00	0.66301922	82.50	0.46782937
0.03	0.00762495	51.50	0.69002220	83.00	0.47332331
1.00	0.01351158	52.00	0.70560098	83.50	0.48591582
2.00	0.02027578	52.50	0.69619348	84.00	0.47298285
3.00	0.02873113	53.00	0.67402851	84.50	0.44295611
4.00	0.03767920	53.50	0.65424785	85.00	0.46294748
5.00	0.04674818	54.00	0.64357470	85.50	0.46122665
6.00	0.05599883	54.50	0.63666694	86.00	0.40824873
7.00	0.06536900	55.00	0.66755142	86.50	0.44597956
8.00	0.07483736	55.50	0.69908039	87.00	0.46346468
9.00	0.09440099	56.00	0.68887103	87.36	0.47879840
10.00	0.09405419	56.50	0.65471416		
11.00	0.10379770	57.00	0.61323788		
12.00	0.11362890	57.50	0.66665722		
13.00	0.12354701	58.00	0.70140956		
14.00	0.13355639	58.50	0.71396172		
15.00	0.14478727	59.00	0.75022750		
16.00	0.15626729	59.50	0.73973008		
17.00	0.16207794	60.00	0.72388091		
18.00	0.17282246	60.50	0.70768429		
19.00	0.18469792	61.00	0.69737383		
20.00	0.19649616	61.50	0.58944275		
21.00	0.20370663	62.00	0.60110129		
22.00	0.21174395	62.50	0.63900506		
23.00	0.22058401	63.00	0.65493950		
24.00	0.22895625	63.50	0.64845231		
25.00	0.23276601	64.00	0.63495088		
26.00	0.23640551	64.50	0.61786292		
27.00	0.23980753	65.00	0.58439056		
28.00	0.23395577	65.50	0.54637470		
29.00	0.22561178	66.00	0.54636910		
30.00	0.21689279	66.50	0.64260275		
31.00	0.21107090	67.00	0.66263988		
32.00	0.23803134	67.50	0.64269431		
33.00	0.25443693	68.00	0.65267087		
34.00	0.25420681	68.50	0.64173718		
35.00	0.26227050	69.00	0.59818311		
36.00	0.28652528	69.50	0.57081982		
37.00	0.30805093	70.00	0.55628933		
38.00	0.33172951	70.50	0.60427142		
39.00	0.34776283	71.00	0.67037328		
40.00	0.32856623	71.50	0.69269650		
40.50	0.31657708	72.00	0.71087826		
41.00	0.29804631	72.50	0.72180998		
41.50	0.29125485	73.00	0.72571167		
42.00	0.30498121	73.50	0.72572915		
42.50	0.32642013	74.00	0.71590476		
43.00	0.34532095	74.50	0.66571985		
43.50	0.36193467	75.00	0.61574847		
44.00	0.37878183	75.50	0.59163169		
44.50	0.41865849	76.00	0.56186985		
45.00	0.46105984	76.50	0.56739373		
45.50	0.50043950	77.00	0.64149242		
46.00	0.52589338	77.50	0.73353732		
46.50	0.54827110	78.00	0.80852047		
47.00	0.56206895	78.50	0.82913507		
47.50	0.55980113	79.00	0.82861187		
48.00	0.55438004	79.50	0.81301056		
48.50	0.53459476	80.00	0.78785523		
49.00	0.50348684	80.50	0.73143381		
49.50	0.47791042	81.00	0.64295070		
50.00	0.52989008	81.50	0.53490356		
50.50	0.60588351	82.00	0.48894147		

TABLE 4-8. MOMENT APPLIED AT STATION 413 VERSUS TIME

TIME	413 M AP (IN-LBS X -06)		ETR WIND OF 6 JULY 1961		
0.00	0.00337503	51.00	1.06273797	82.50	1.13983087
0.03	0.00371670	51.50	1.07648243	83.00	1.15875375
1.00	0.03502396	52.00	1.05906358	83.50	1.20025625
2.00	0.04681596	52.50	1.04338160	84.00	1.18058660
3.00	0.06773882	53.00	1.03808363	84.50	1.17528627
4.00	0.09043731	53.50	1.04754376	85.00	1.35702726
5.00	0.11258354	54.00	1.05484687	85.50	1.28884551
6.00	0.13538935	54.50	1.05992316	86.00	1.24798803
7.00	0.15845678	55.00	1.02297770	86.50	1.20038912
8.00	0.18170325	55.50	1.17169297	87.00	1.13518090
9.00	0.20515565	56.00	1.07030152	87.36	1.21124980
10.00	0.22878232	56.50	1.10889208		
11.00	0.25258049	57.00	1.18749413		
12.00	0.27653861	57.50	1.41277720		
13.00	0.30064428	58.00	1.52129284		
14.00	0.32490610	58.50	1.57520994		
15.00	0.35189215	59.00	1.66992870		
16.00	0.39416363	59.50	1.71905530		
17.00	0.38729633	60.00	1.70834502		
18.00	0.41625611	60.50	1.61034940		
19.00	0.44365922	61.00	1.44172444		
20.00	0.47069406	61.50	1.46657842		
21.00	0.48672855	62.00	1.21281862		
22.00	0.50520105	62.50	1.35767570		
23.00	0.52622106	63.00	1.41524472		
24.00	0.54680441	63.50	1.41556834		
25.00	0.55742623	64.00	1.39424478		
26.00	0.56873740	64.50	1.35990730		
27.00	0.58065685	65.00	1.27438290		
28.00	0.56574335	65.50	1.26739820		
29.00	0.54236697	66.00	1.57223550		
30.00	0.51865125	66.50	1.71142432		
31.00	0.50005736	67.00	1.75554530		
32.00	0.59076003	67.50	1.77128264		
33.00	0.61651370	68.00	1.82681174		
34.00	0.59344466	68.50	1.83370624		
35.00	0.61532389	69.00	1.74248382		
36.00	0.69215598	69.50	1.66596936		
37.00	0.75262661	70.00	1.62785170		
38.00	0.81055095	70.50	1.74693682		
39.00	0.85071288	71.00	1.91329522		
40.00	0.80104650	71.50	1.99466492		
40.50	0.77553125	72.00	2.04283202		
41.00	0.70956719	72.50	2.06499252		
41.50	0.67850053	73.00	2.04846084		
42.00	0.74224581	73.50	2.02199326		
42.50	0.81573710	74.00	1.99911544		
43.00	0.86986950	74.50	1.88155936		
43.50	0.91519673	75.00	1.73181740		
44.00	0.95846801	75.50	1.60176588		
44.50	1.02103781	76.00	1.40284756		
45.00	1.09213758	76.50	1.32655203		
45.50	1.15762710	77.00	1.60825282		
46.00	1.18631840	77.50	1.89335944		
46.50	1.20418756	78.00	2.11909786		
47.00	1.20379683	78.50	2.18906750		
47.50	1.16632007	79.00	2.18181492		
48.00	1.12132047	79.50	2.12480112		
48.50	1.05250308	80.00	2.05185610		
49.00	0.97172692	80.50	1.90775706		
49.50	0.93706896	81.00	1.68039694		
50.00	0.83747006	81.50	1.37699038		
50.50	0.98399172	82.00	1.21502985		

TABLE 4-9. MOMENT APPLIED AT STATION 812 VERSUS TIME

TIME	812 M AP (IN-LBS X -06)			ETR WIND OF 6 JULY 1961	
0.00	0.11013396	51.00	1.57069196	82.50	1.98518524
0.03	0.11022235	51.50	1.65024574	83.00	2.07470140
1.00	0.02919781	52.00	1.71504820	83.50	2.14003812
2.00	0.08092748	52.50	1.80288000	84.00	1.97810350
3.00	0.09861802	53.00	1.89987342	84.50	1.64505800
4.00	0.10601729	53.50	1.98037326	85.00	1.36765860
5.00	0.12319993	54.00	2.02820252	85.50	1.23956576
6.00	0.15461623	54.50	2.08057084	86.00	1.21298363
7.00	0.19036364	55.00	2.02312452	86.50	1.18151391
8.00	0.22248226	55.50	1.96191274	87.00	1.04936522
9.00	0.25495831	56.00	1.90838682	87.36	1.36449578
10.00	0.28807071	56.50	1.88481144		
11.00	0.32168611	57.00	2.03044424		
12.00	0.35568307	57.50	2.29626466		
13.00	0.38993545	58.00	2.49880892		
14.00	0.42445093	58.50	2.58408170		
15.00	0.46228078	59.00	2.70344436		
16.00	0.59748735	59.50	2.86624148		
17.00	0.49604195	60.00	2.64371220		
18.00	0.55428904	60.50	2.71992656		
19.00	0.59570089	61.00	2.53799194		
20.00	0.63757605	61.50	2.45819062		
21.00	0.66642360	62.00	2.46575966		
22.00	0.70135189	62.50	2.58413844		
23.00	0.74166736	63.00	2.69175972		
24.00	0.78366325	63.50	2.69616424		
25.00	0.81578582	64.00	2.66396362		
26.00	0.85098570	64.50	2.63109570		
27.00	0.88792495	65.00	2.59590236		
28.00	0.87609455	65.50	2.60225916		
29.00	0.84543755	66.00	2.65034194		
30.00	0.83388687	66.50	2.82944692		
31.00	0.79974075	67.00	3.00307052		
32.00	0.77889770	67.50	3.07219188		
33.00	0.87306637	68.00	3 [illegible]225752		
34.00	0.88645172	68.50	3.16819532		
35.00	0.92054370	69.00	3.05327012		
36.00	0.93947500	69.50	2.90290980		
37.00	1.01019941	70.00	2.84394140		
38.00	1.10412118	70.50	3.00851988		
39.00	1.17535712	71.00	3.29298888		
40.00	1.09565481	71.50	3.46987072		
40.50	1.08137696	72.00	3.53844588		
41.00	0.99518962	72.50	3.60500000		
41.50	1.11995201	73.00	3.59756224		
42.00	1.24329058	73.50	3.56268728		
42.50	1.34158922	74.00	3.52827904		
43.00	1.41109596	74.50	3.38228168		
43.50	1.46955320	75.00	3.16247552		
44.00	1.52723084	75.50	2.99960752		
44.50	1.61441884	76.00	2.75667720		
45.00	1.72030876	76.50	2.34552580		
45.50	1.82702112	77.00	2.34529586		
46.00	1.87599936	77.50	2.80156540		
46.50	1.90122400	78.00	3.24642976		
47.00	1.90727482	78.50	3.44047464		
47.50	1.85708274	79.00	3.46907848		
48.00	1.78700824	79.50	3.39607920		
48.50	1.69969750	80.00	3.27317428		
49.00	1.59045730	80.50	2.99138424		
49.50	1.53639712	81.00	2.56916074		
50.00	1.50077246	81.50	2.05180014		
50.50	1.48529710	82.00	1.91326794		

TABLE 4-10. AXIAL LOAD APPLIED AT STATION 217 VERSUS TIME

TIME	217 P APP. (LBS X -03)			ETR WIND OF 6 JULY 1961	
0.00	2.49985432	51.00	54.24819840	82.50	27.89486304
0.03	2.50026330	51.50	56.51136000	83.00	27.69326880
1.00	2.51592882	52.00	56.57986824	83.50	27.52425376
2.00	2.53884112	52.50	56.60854080	84.00	27.34887872
3.00	2.56851758	53.00	56.58837120	84.50	27.10285504
4.00	2.60803300	53.50	56.47096084	85.00	26.78541760
5.00	2.65184224	54.00	56.30776512	85.50	26.43778912
6.00	2.70591204	54.50	56.09110400	86.00	26.12806048
7.00	2.76930518	55.00	56.10319424	86.50	25.82993632
8.00	2.84259788	55.50	56.11048384	87.00	25.53926272
9.00	2.92809500	56.00	56.03497024	87.36	25.34297056
10.00	3.02046372	56.50	55.90738064		
11.00	3.12632044	57.00	55.69809280		
12.00	3.24423112	57.50	55.42012224		
13.00	3.37475704	58.00	55.24237440		
14.00	3.51856152	58.50	55.16274688		
15.00	3.67861404	59.00	54.99490888		
16.00	3.84928220	59.50	54.84079552		
17.00	4.03983640	60.00	54.70773952		
18.00	4.24715888	60.50	54.42067200		
19.00	4.47218908	61.00	54.13745024		
20.00	4.71501780	61.50	53.68935232		
21.00	4.97130380	62.00	53.18675456		
22.00	5.24577728	62.50	52.63269312		
23.00	5.53918800	63.00	52.01729664		
24.00	5.85136264	63.50	51.33776832		
25.00	6.18178128	64.00	50.62151360		
26.00	6.53218128	64.50	49.85405696		
27.00	6.90289056	65.00	49.02976768		
28.00	7.29899544	65.50	48.17250752		
29.00	7.71767200	66.00	47.25375680		
30.00	8.15811640	66.50	46.27758592		
31.00	8.62412448	67.00	45.25557184		
32.00	9.11111624	67.50	44.18591744		
33.00	9.62001608	68.00	43.06795840		
34.00	10.15126328	68.50	41.90545920		
35.00	10.70754280	69.00	40.67945280		
36.00	11.29368656	69.50	39.40216832		
37.00	11.90404592	70.00	38.54858784		
38.00	12.54186624	70.50	38.04946016		
39.00	13.19688960	71.00	37.54344064		
40.00	13.85231312	71.50	37.03697216		
40.50	14.18730448	72.00	36.50531584		
41.00	14.52382416	72.50	35.95373280		
41.50	14.86307200	73.00	35.37722016		
42.00	15.25588512	73.50	34.76992192		
42.50	15.69066176	74.00	34.12160096		
43.00	16.13737696	74.50	33.47557472		
43.50	16.59759008	75.00	32.80380640		
44.00	17.06649888	75.50	32.10213632		
44.50	17.53961536	76.00	31.57426240		
45.00	18.02108288	76.50	31.20499616		
45.50	18.51351648	77.00	30.85588192		
46.00	19.84434496	77.50	30.45148160		
46.50	21.71063392	78.00	30.00902656		
47.00	23.69872480	78.50	29.51284512		
47.50	25.84266976	79.00	29.02127616		
48.00	28.09040512	79.50	28.92966592		
48.50	30.50405824	80.00	28.85637792		
49.00	33.04187904	80.50	28.76492352		
49.50	37.50872672	81.00	28.55363456		
50.00	42.80195264	81.50	28.29063104		
50.50	48.43002816	82.00	28.10616384		

TABLE 4-11. AXIAL LOAD APPLIED AT STATION 413 VERSUS TIME

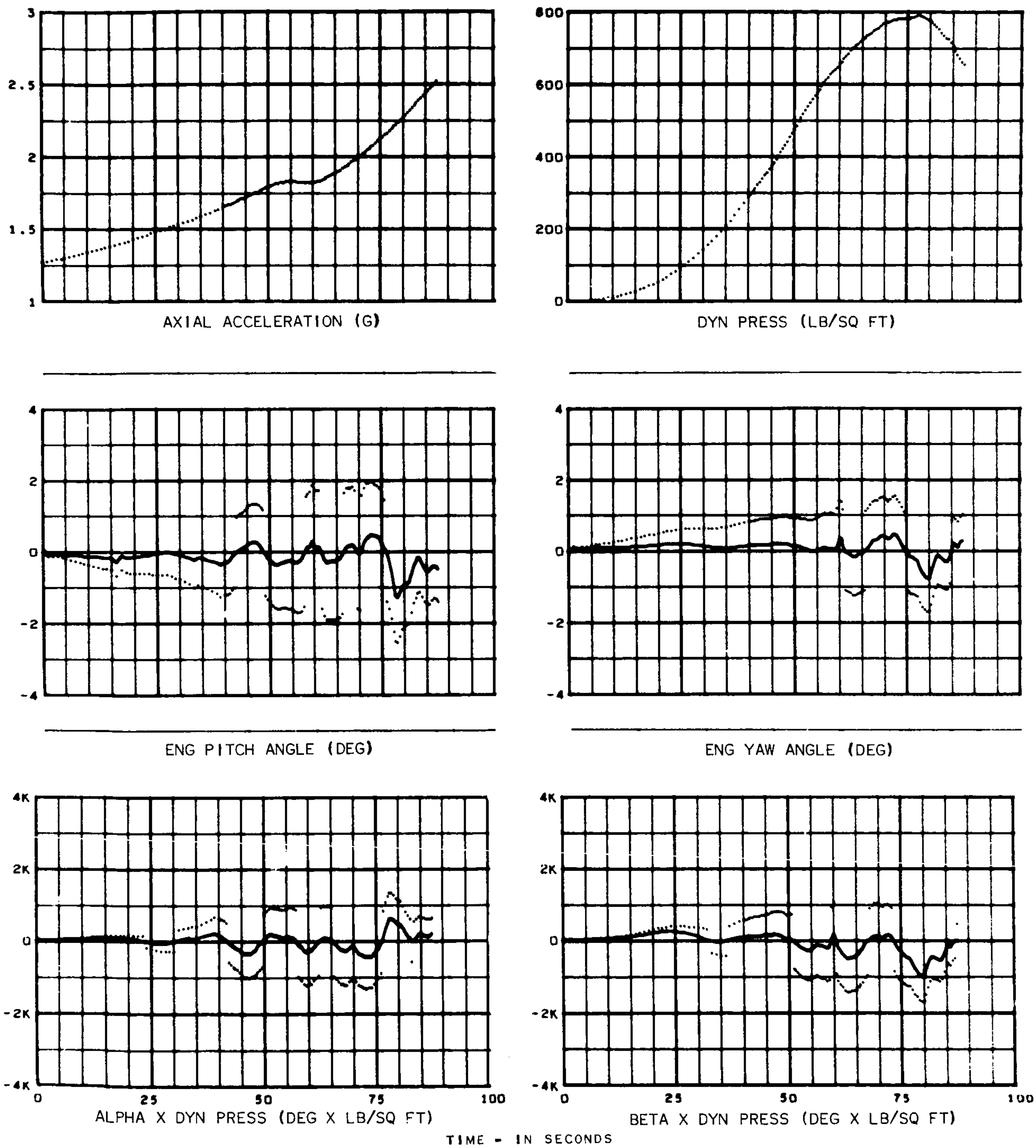
TIME	413 F APP.	(LBS X -03)		ETR	WIND OF 6 JULY 1961
0.00	50.23635072	51.00	92.13423104	82.50	127.35846656
0'.03	50.24449472	51.50	93.37294464	83.00	127.67582464
1.00	50.50158464	52.00	94.66536064	83.50	128.04118400
2.00	50.77763264	52.50	95.98648448	84.00	128.39470208
3.00	51.06459776	53.00	97.32403328	84.50	128.64569984
4.00	51.36322624	53.50	98.68693760	85.00	128.80991104
5.00	51.67287616	54.00	100.07710848	85.50	128.94126976
6.00	51.99491776	54.50	101.49978112	86.00	129.12502656
7.00	52.33008448	55.00	103.50098048	86.50	129.33323648
8.00	52.67864320	55.50	105.61424640	87.00	129.55215488
9.00	53.04092608	56.00	107.71294848	87.36	129.73401984
10.00	53.41798464	56.50	109.82781056		
11.00	53.81035968	57.00	111.90299648		
12.00	54.21867584	57.50	113.94619904		
13.00	54.64307008	58.00	115.74882304		
14.00	55.08464448	58.50	117.12679936		
15.00	55.54440768	59.00	118.39733760		
16.00	56.02244800	59.50	119.83411328		
:7.00	56.56432768	60.00	121.55008128		
18.00	57.13030400	60.50	122.99127040		
19.00	57.72187712	61.00	124.18696064		
20.00	58.33958464	61.50	124.38117120		
21.00	58.92135232	62.00	124.53924096		
22.00	59.52559808	62.50	124.69943168		
23.00	60.15326464	63.00	124.84482688		
24.00	60.80444608	63.50	124.[illegible]865536		
25.00	61.47543808	64.00	125.04800000		
26.00	62.17123840	64.50	125.10729600		
27.00	62.89219520	65.00	125.12064384		
28.00	63.64261184	65.50	125.11726080		
29.00	64.41604224	66.00	125.06617984		
30.00	65.21639040	66.50	124.98614784		
31.00	66.04691520	67.00	124.89628160		
32.00	66.90426624	67.50	124.78666368		
33.00	67.78356544	68.00	124.63237760		
34.00	68.69095680	68.50	124.46320768		
35.00	69.62827008	69.00	124.30630144		
36.00	70.59969024	69.50	124.09081856		
37.00	71.59300992	70.00	124.03811456		
38.00	72.61924608	70.50	124.10267904		
39.00	73.67090624	71.00	124.18434560		
40.00	74.73606912	71.50	124.29064576		
40.50	75.27358848	72.00	124.37559424		
41.00	75.81573760	72.50	124.43477760		
41.50	76.36310080	73.00	124.47233920		
42.00	76.95714560	73.50	124.48122368		
42.50	77.58803392	74.00	124.45181568		
43.00	78.23162560	74.50	124.45696896		
43.50	78.88932800	75.00	124.44211584		
44.00	79.55232448	75.50	124.39577600		
44.50	80.21481280	76.00	124.44897024		
45.00	80.88693760	76.50	124.57115648		
45.50	81.57077760	77.00	124.73188480		
46.00	82.33676480	77.50	124.82660096		
46.50	83.14990080	78.00	124.87918720		
47.00	83.98973248	78.50	124.87017088		
47.50	84.86539200	79.00	124.87511424		
48.00	85.74723264	79.50	125.33308416		
48.50	86.64985344	80.00	125.79752960		
49.00	87.57293184	80.50	126.22425600		
49.50	88.63338752	81.00	126.50631424		
50.00	89.76807168	81.50	126.73048704		
50.50	90.94415488	82.00	127.05940608		

TABLE 4-12. AXIAL LOAD APPLIED AT STATION 812 VERSUS TIME

TIME	812 P APP. (LBS X -03)			ETR WIND OF 6 JULY 1961	
0.00	52.39886784	51.00	83.85832000	82.50	121.08449280
0.03	52.40736000	51.50	84.75072640	83.00	121.54457984
1.00	52.67387744	52.00	85.70127744	83.50	122.03882624
2.00	52.95588240	52.50	86.66825600	84.00	122.52383816
3.00	53.24520768	53.00	87.65246848	84.50	122.93634560
4.00	53.54222080	53.50	88.65836544	85.00	123.29343104
5.00	53.84593280	54.00	89.68793984	85.50	123.63105536
6.00	54.15746752	54.50	90.74333568	86.00	124.00574208
7.00	54.47728448	55.00	92.04016640	86.50	124.39819904
8.00	54.80534400	55.50	93.39084144	87.00	124.79900544
9.00	55.14187168	56.00	94.73832448	87.36	125.10676096
10.00	55.48704768	56.50	96.09289600		
11.00	55.84168064	57.00	97.43078784		
12.00	56.20590784	57.50	98.75517952		
13.00	56.57954304	58.00	100.00134400		
14.00	56.96337792	58.50	101.08306560		
15.00	57.35792000	59.00	102.10476544		
16.00	57.76305792	59.50	103.25417984		
17.00	58.22572608	60.00	104.63781760		
18.00	58.70396352	60.50	105.84958848		
19.00	59.19883712	61.00	106.86182400		
20.00	59.71091008	61.50	107.14181120		
21.00	60.17626240	62.00	107.40391936		
22.00	60.65473600	62.50	107.69108736		
23.00	61.14692288	63.00	107.98562560		
24.00	61.65309312	63.50	108.26148864		
25.00	62.16964032	64.00	108.54573184		
26.00	62.70091008	64.50	108.80720896		
27.00	63.24714624	65.00	109.04721536		
28.00	63.80990592	65.50	109.28137984		
29.00	64.38408704	66.00	109.49354368		
30.00	64.97445248	66.50	109.69612416		
31.00	65.58226240	67.00	109.89832704		
32.00	66.20681344	67.50	110.09411968		
33.00	66.84237568	68.00	110.26843136		
34.00	67.49538048	68.50	110.43439104		
35.00	68.16626432	69.00	110.62138496		
36.00	68.85671360	69.50	110.77945600		
37.00	69.55716864	70.00	111.04187520		
38.00	70.27761664	70.50	111.37722496		
39.00	71.01630784	71.00	111.73388800		
40.00	71.77054464	71.50	112.11574144		
40.50	72.14912512	72.00	112.48887680		
41.00	72.53210624	72.50	112.84552960		
41.50	72.91942848	73.00	113.19295616		
42.00	73.33822528	73.50	113.52704384		
42.50	73.78108160	74.00	113.84345088		
43.00	74.23246912	74.50	114.19323008		
43.50	74.69291584	75.00	114.53606784		
44.00	75.15584448	75.50	114.86262016		
44.50	75.61752064	76.00	115.25686528		
45.00	76.08552992	76.50	115.69381888		
45.50	76.56386240	77.00	116.17033088		
46.00	77.09737408	77.50	116.60179968		
46.50	77.66699584	78.00	117.00701056		
47.00	78.25356608	78.50	117.36810880		
47.50	78.86133760	79.00	117.73710464		
48.00	79.47025280	79.50	118.28843648		
48.50	80.08450048	80.00	118.83713920		
49.00	80.71335040	80.50	119.35538304		
49.50	81.44292480	81.00	119.78268928		
50.00	82.22512512	81.50	120.17554560		
50.50	83.03460544	82.00	120.63887616		

ATLAS/CENTAUR (AC-6) FLIGHT WIND RESTRICTION
ETR WIND OF 6 JULY 1961

THRUST, WDOT, INITIAL WT, PITCH PROG GD/A63-0495-21
AP GAINS AY63-0071-6 AERO COEFF GD/A-BTD64-062
CG, INER CW65-60 BEMO COEFF GD/A-BTD64-062
RUN DATE 7 MAY 1965

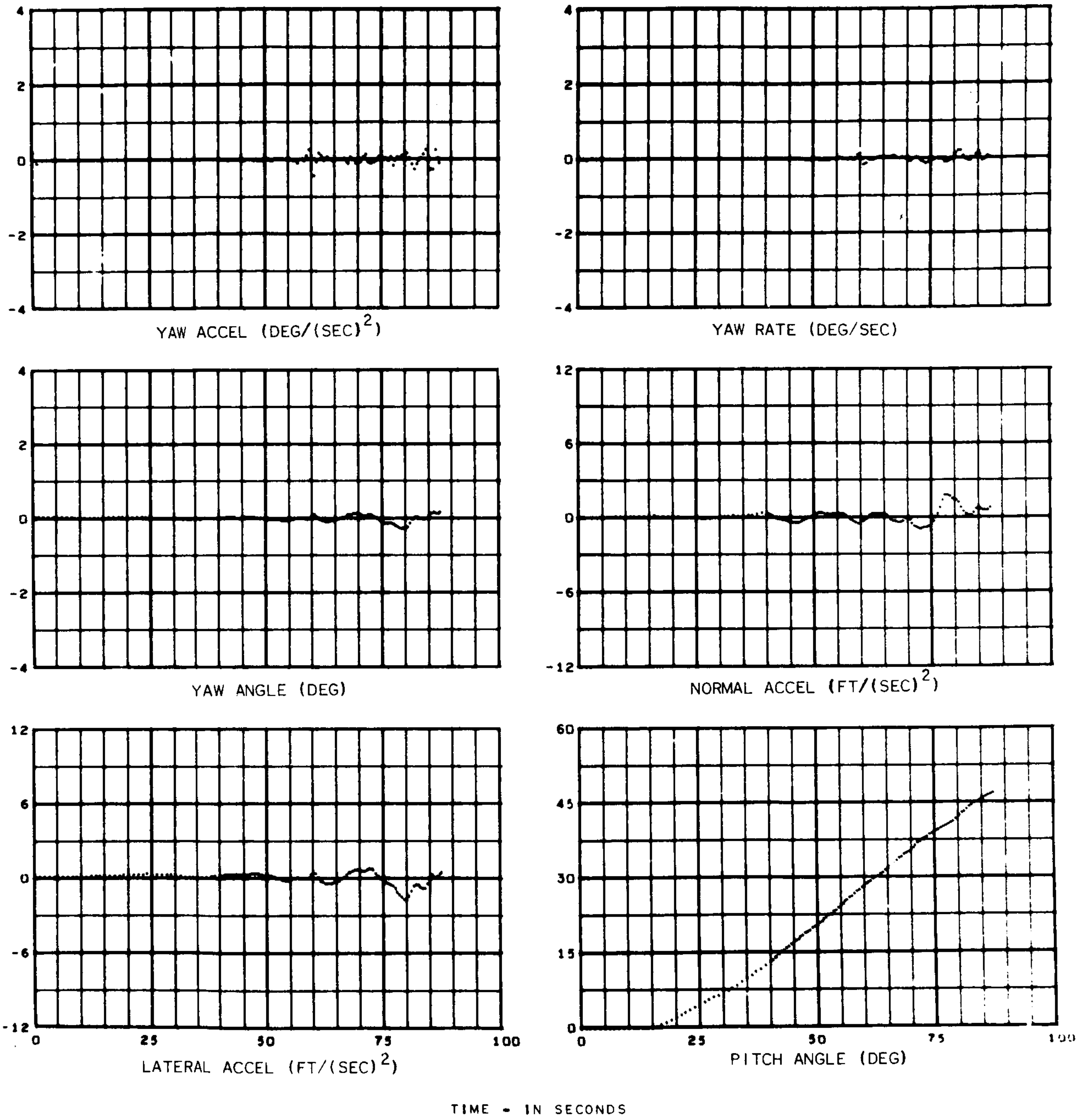


4E09SV

Figure 4-3. Axial Acceleration, Dynamic Pressure, Engine Pitch and Yaw Angles, αq and βq versus Time

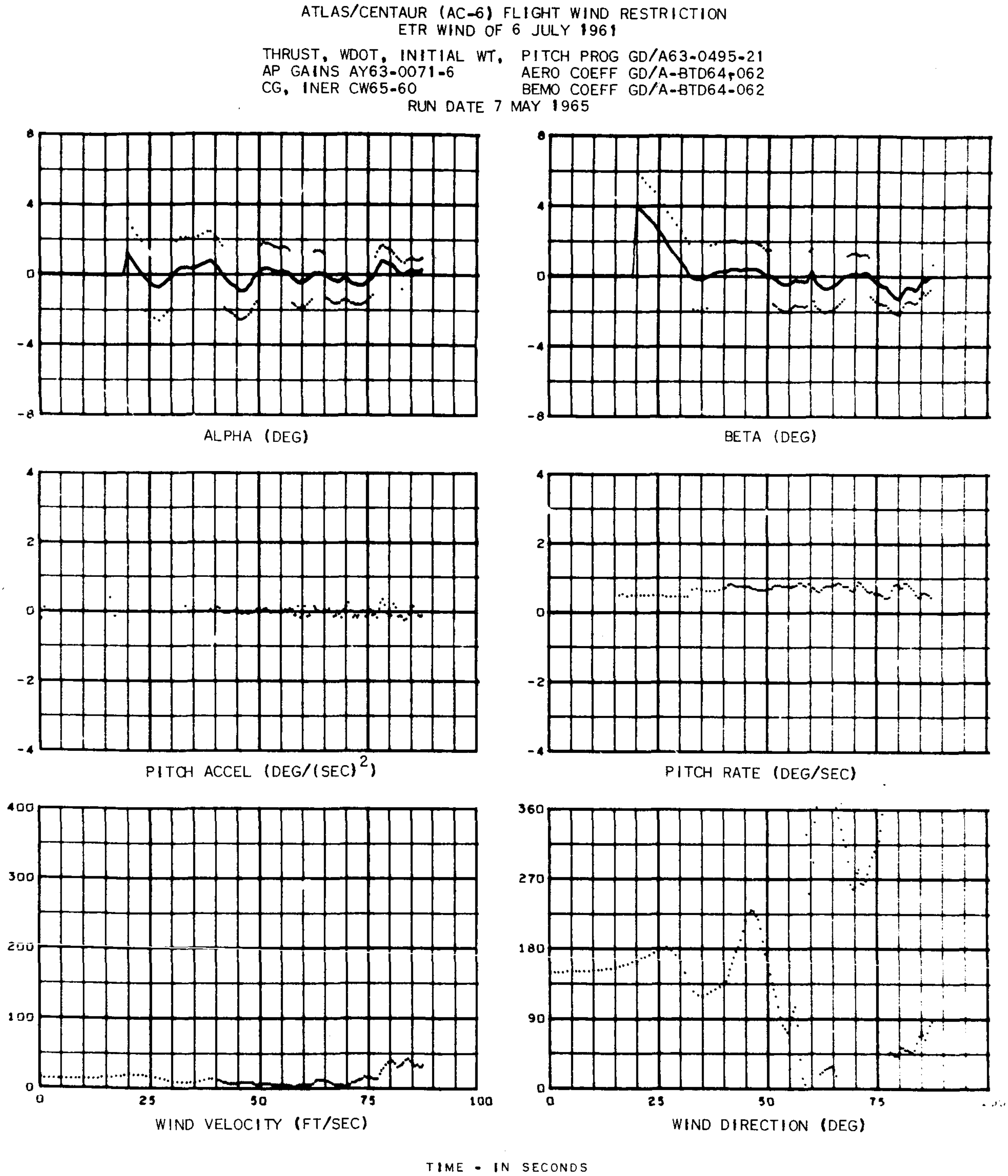
ATLAS/CENTAUR (AC-6) FLIGHT WIND RESTRICTION
ETR WIND OF 6 JULY 1961

THRUST, WDOT, INITIAL WT, PITCH PROG GD/A63-0495-21
AP GAINS AY63-0071-6 AERO COEFF GD/A-BTD64-062
CG, INER CW65-60 BEMO COEFF GD/A-BTD64-062
RUN DATE 7 MAY 1965



4E10SV

Figure 4-4. Yaw Acceleration, Rate, and Angle, Normal and Lateral Accelerations, and Pitch Angle versus Time

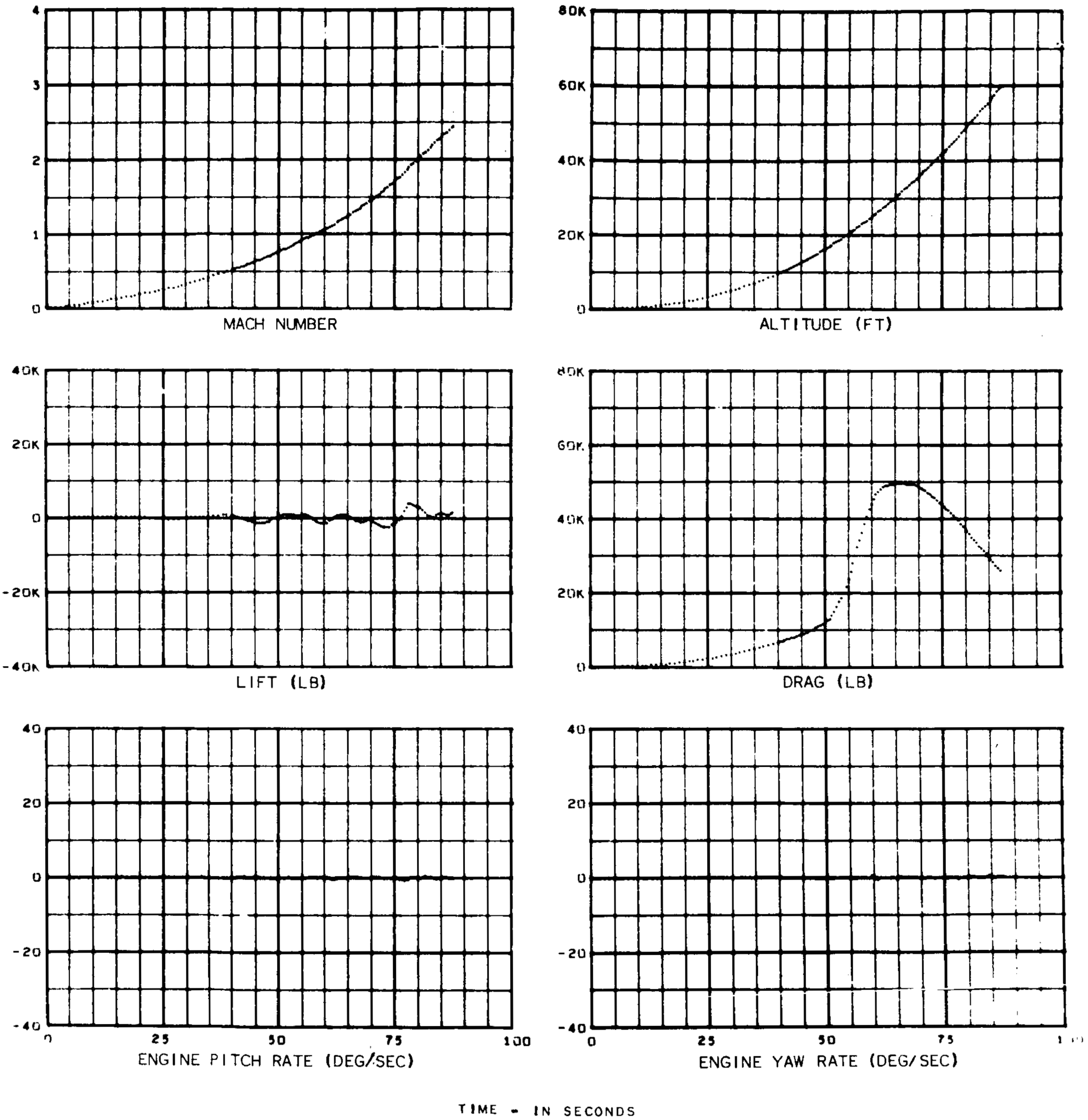


4E11SV

Figure 4-5. Alpha, Beta, Pitch Acceleration and Rate, Wind Velocity and Direction versus Time

ATLAS/CENTAUR (AC-6) FLIGHT WIND RESTRICTION
ETR WIND OF 6 JULY 1961

THRUST, WDOT, INITIAL WT, PITCH PROG GD/A63-0495-21
AP GAINS AY 63-0071-6 AERO COEFF GD/A-BTD64-062
CG, INER CW65-60 BEMO COEFF GD/A-BTD64-062
RUN DATE 7 MAY 1965



4E12SV

Figure 4-6. Mach Number, Altitude, Lift, Drag, and Engine Pitch and Yaw Rates versus Time

SECTION V

PROCEDURE FOR TRANSMISSION OF WIND-DATA AND FLIGHT-SIMULATION RESULTS

5.1 TRANSMISSION OF WIND DATA TO GENERAL DYNAMICS/CONVAIR, SAN DIEGO

The purpose of this section is to present the procedures to be used in determining whether safe upper-atmosphere wind conditions exist for launching an Atlas/Centaur vehicle.

5.1.1 AIR FORCE WEATHER GROUP. The Air Force Eastern Test Range (ETR) 4th Weather Group shall obtain wind speed in knots and direction in degrees-from-north for altitudes up to 50,000 feet using standard weather balloons with AN-GMD-la equipment.

Depending upon the availability of the FPS-16 Radar and the CDC 3600 digital computer at the Range Central Control Building, an attempt will be made on AC-6 to obtain and use flight-wind profiles made with the high resolution FPS-16 Radar and the mylar Jimsphere balloon which has surface roughness (caused by randomly-spaced cones) to control oscillatory motion.

5.1.2 LAUNCH-TIME WIND FORECASTING. Wind forecasts for launch time shall be provided at 5,000-foot intervals on F-2D (days), F-1D, and also at T-10H (hours) if special weather conditions are forecast.

5.1.3 WIND DATA. Wind data will be taken at 1,000-foot altitude intervals, or, if the FPS-16 Radar is available, it will be taken at 25-meter intervals. These data, plus comments on trends and critical shears, shall be provided to the General Dynamics/Convair (GD/C) test operations representative at the ETR weather office from balloons released at T-12H, T-7H, T-4H, T-3H, T-2H, and approximately every hour thereafter until the vehicle is launched or scrubbed. A balloon shall also be released immediately after the vehicle is launched to verify measured inflight loads.

5.1.4 WIND SPEED AND DIRECTION VALUES. The wind-speed and direction values are to be on punched cards compatible with the GD/C COMBO Trajectory Program. The data shall be transmitted to GD/C, San Diego, via the IBM 1001 Data Transmitter located in the Range Central Control Building or the IBM 066-068 Data Transmitter located in Hangar J.

5.2 FLIGHT-SIMULATION PROCEDURE

5.2.1 PUNCHED CARDS. The punched cards will be received at the IBM 026 key-punch Model 5 or IBM 066-068 via Data-Phone located in Building 4 at GD/C, San Diego, and automatically verified.

5.2.2 PROGRAMMING. The punched cards shall then be inserted by the Digital Computer Laboratory programmer into the program deck used for the COMBO/Autopilot - Bending Moments/Axial Loads Program for simulation of the AC-6 Centaur flight. The program shall then be run on an immediate priority basis on the IBM 7094 computer.

5.2.3 SC 4020 MICROFILM RECORDER. The GD/C Processing Group representatives shall take the program output tape and put it on the Stromberg-Carlson 4020 microfilm recorder for immediate display of results. The Load Capability Ratio, Structural Capability Ratio, design-limit engine deflections, calculated engine deflections, and other flight parameters will be plotted.

5.2.4 CRITICAL WINDS. In the event of critical winds, additional soundings may be requested. Three hours advance notice is desirable.

5.2.5 TRANSMISSION OF DATA. In case of failure in the Data-Phone transmission to San Diego, wind observations shall be transmitted to the GD/C Dynamics Group via commercial telephone. Forecasts shall be forwarded by telephone tie-line; commercial phone shall be used if the tie-line is unavailable.

5.2.6 PERSONNEL AVAILABILITY. Personnel, locations, and phone numbers for this operation are provided in detail in GD/C Dynamics Memo SD-65-123-CEN, Events, Communications Network, and People Cognizant to the Flight Wind Restriction Procedure for the Atlas/Centaur AC-6 Flight, which shall be kept up-to-date.

5.2.7 PRELAUNCH REQUIREMENTS. The requirements for prelaunch wind-restriction data stated herein, as well as other wind data requirements, are detailed in the Centaur Program Requirements Document, PRD 800.

5.3 TRANSMISSION OF RESULTS TO THE EASTERN TEST RANGE

5.3.1 DATA CALCULATIONS. GD/C Dynamics and Structures representatives shall check data for validity and calculate the following:

a. For the most critical stations and times, the Load Capability and Structural Capability Ratios
b. For the most critical plane and time, the ratio of calculated engine deflection to design-limit engine deflection ($\delta_{CALC}/\delta_{DL}$).

5.3.2 COMMUNICATIONS PRIORITY. The resultant data, plus any special comments, shall be transmitted via priority telephone WATS line by the GD/C Dynamics Group representative to the GD/C ETR flight-wind coordinator in Complex 36. The GD/C flight-wind coordinator shall, in turn, pass this information on to the test conductor. The telephoned data shall be confirmed by TWX.

5-4. SCHEDULE OF EVENTS FOR A TYPICAL SOUNDING

Table 5-1 is the expected schedule of events for a typical sounding, from balloon release to delivery of simulation results to ETR. Approximately eighty-seven flight profiles were run during the attempts to launch Atlas/Centaur vehicles F-1, AC-2, AC-3, AC-4, and AC-5. Time estimates are based upon these past efforts and upon the anticipated time savings using transmission of the wind-profile velocity and direction as specified.

TABLE 5-1. SCHEDULE OF EVENTS FOR A TYPICAL SOUNDING

Events	Total Time from Release of Balloon at ETR	Time between Events
1. Release balloon at ETR	0 min	
		60 min
2. Balloon at 50,000feet	60	
		3
3. Data on tape	63	
		5
4. Teletype transmission to ETR	68	
		11
5. Wind velocity and direction cards off IBM computer at ETR	79	
		0 to 14*
6. Start transmission of data to GD/C (San Diego) via IBM 1001 or IBM 066-068 and Data-Phone	79-93	
		5
7. Data received at GD/C and put on IBM 7094	84-98	
		7
8. Data displayed on SC 4020	91-105	
		3
9. GD/C completes call to Complex 36.	94-108	

NOTE:
*Meteorological evaluation will be performed concurrently with GD/C analysis. A re-run on the IBM 1620 or CDC 3600 will cost 14 minutes.

5.5 LAUNCH RECOMMENDATION

5.5.1 LAUNCH AVAILABILITY. The Load Capability Ratio for the most critical flight time and vehicle station and the ratio of the calculated engine deflection to the design-limit engine deflection ($\delta_{CALC}/\delta_{DL}$) for the most critical time and plane shall be used. It is recommended that these two numbers, plus their trend from previous soundings and simulations, be used to make countdown and launch decisions according to Table 5-2. These recommendations may, of course, be modified by special weather forecast details such as the approach of a storm front. The Structural Capability Ratio will not be used in determining the launch recommendation. This ratio is only for information purposes.

5.5.2 SOUNDINGS AND RECOMMENDATIONS. These soundings and recommendations support the following prelaunch events:

a. The F-2D forecast serves as an early alert to the possibility of wind restriction and also to ascertain that the simulation and display are functioning properly.

b. The F-1D forecast is timed to give simulation results back to ETR by 11:00 am on F-1D day. These results shall then be considered, together with the status of all vehicle and support systems, before notifying the range of final intent to launch the following day.

c. The T-12H sounding shall provide simulation results at ETR prior to the start of precount and countdown in the event that the winds have increased greatly over those forecast. This is to preclude the attendent probability of restriction due to very high-force winds.

d. The T-7H sounding simulation results shall be available to give a better estimate of wind-restriction probability before the start of tower removal.

e. The T-4H and T-3H sounding simulation results will be available at the time of the first liquid oxygen tanking.

f. After the Centaur liquid oxygen tanking, additional soundings shall be made at the minimum possible intervals (approximately 1 hour). These soundings will be identified as T-2H-X, X being the sequence numbers, -1, -2, etc., as required.

TABLE 5-2. LAUNCH DECISION RECOMMENDATIONS

<table>
<tr><th rowspan="2">Balloon Launch</th><th rowspan="2">Simulation Results Received at Complex 36</th><th colspan="7">Load Capability Ratio or Deflection Ratio (LCR or $\delta_{CALC}/\delta_{DL}$)</th></tr>
<tr><th>> 1.3</th><th colspan="2">1.15 to 1.3</th><th>>1.0 to 1.15</th><th colspan="2">0.95 to 1.0</th><th><0.95</th></tr>
<tr><td>F-2D
11:00 am EST
8:00 am PST</td><td>F-2D
2:00 pm EST
11:00 am PST</td><td colspan="7">For information and flight simulation checkout.</td></tr>
<tr><td>F-1D
11:00 am EST
8:00 am PST</td><td>F-1D
2:00 pm EST
11:00 am PST</td><td>**</td><td colspan="2">Go</td><td>Go</td><td colspan="2">Go</td><td>Go</td></tr>
<tr><td rowspan="2">T-12H</td><td rowspan="2">T-5H*</td><td rowspan="2">**</td><td>I</td><td>**</td><td rowspan="2">Go</td><td colspan="2" rowspan="2">Go</td><td rowspan="2">Go</td></tr>
<tr><td>D</td><td>Go</td></tr>
<tr><td>T-7H</td><td>T-4H</td><td>**</td><td colspan="2">Hold(1)</td><td>Hold(1)</td><td colspan="2">Go</td><td>Go</td></tr>
<tr><td>T-4H</td><td>T-2H</td><td rowspan="2">**</td><td>I</td><td>**</td><td rowspan="2">Hold(2)</td><td>I</td><td>Hold(2)</td><td rowspan="2">Go</td></tr>
<tr><td>T-3H</td><td>T-75 Min</td><td>D</td><td>Hold(2)</td><td>D</td><td>Go</td></tr>
<tr><td rowspan="2">T-2H -X</td><td rowspan="2">T-5 Min</td><td rowspan="2">**</td><td>I</td><td>**</td><td rowspan="2">Hold(2)</td><td>I</td><td>Hold</td><td rowspan="2">Go</td></tr>
<tr><td>D</td><td>Hold(2)</td><td>D</td><td>Go</td></tr>
</table>

(1) Continue countdown until tower removal and hold until next sounding gives ratio less than 1.0.

(2) Hold at start of Centaur LO_2 tanking until next sounding gives ratio less than 1.0.

I - Critical load increased from previous sounding.

D - Critical load decreased from or remained same as previous sounding.

The X in T-2H -X is the sequence number in the event of a hold after the first LO_2 tanking.

* The T-12H data will be analyzed immediately prior to the T-7H data.
** Unfavorable.

SECTION VI

REFERENCES

6.1 REFERENCE NUMBERING

The reference documents cited in the text of this report are chronologically listed in this section. Each such reference is assigned a chronological number in the same sequence as it first appears in the report, by section and order. The same number is then maintained throughout the report on all subsequent referrals to the previously cited document, regardless of the section in which the referral appears.

6.2 REFERENCES CITED

2-1 Gust Response Program Number 2466, A. L. Odorico. Memo No. CCD-PROG-012, 25 September 1964 (General Dynamics/Astronautics).

2-2 Atlas/Centaur, AC-6, Bending Moments and Engine Deflections for the Standard Autopilot, Due to 30 Ft/Sec Wind Gusts, T.E. Johnson. Memo No. SD-65-125-CEN, 26 May 1965 (General Dynamics/Convair).

2-3 Atlas/Centaur Launch Availability, K. Kachigan. Memo 10 September 1964 (General Dynamics/Astronautics).

2-4 Supplemental (No Wind) AC-6 Design Trajectory Parameters, T. J. Pavlick. Memo No. CA-FM-116, 30 March 1965 (General Dynamics/Convair).

2-5 CDC-160A Digital Computer Program for Computing Equivalent Bending Moments Due to Uncorrelated, Random Flight Loads for the Atlas/Centaur Vehicle, R. T. Mattson. Memo SD-65-112-CEN, 13 April 1965 (General Dynamics/Convair).

2-6 Flight Dynamics and Control Analysis of the LV-3C Launch Vehicle (Atlas/Centaur AC-6 and AC-7), P. McGowan. Report Number GD/C-DDE65-021, April 1965 (General Dynamics/Convair).

2-7 Static Aeroelastic Program Number 3558, A. L. Odorico. Memo No. CCD-PROG-013, October 1964 (General Dynamics/Astronautics).

2-8 Atlas/Centaur, AC-6, Static Aeroelastic Factors, R.M. Hintz. Memo No. SD-65-124-CEN, 26 May 1965 (General Dynamics/Convair).

3-1 Ultimate Bending Moment and Axial Load for Use in the Flight Wind Restriction Procedure between 45 and 90 Seconds for AC-4 through AC-15, R. Holt. Memo SD-64-157-CEN, 9 September 1964 (General Dynamics/Astronautics).

3-2 Ultimate Allowable Bending Moments and Axial Loads for Use in the Flight Wind Restriction Procedure for the LV-3C/AC-6 Launch Vehicle, N. D. Viste. Memo No. 587-265-4, 6 April 1965 (General Dynamics/Convair).

3-3 Axial Load and Bending Moment Allowables for AC-6 Flight Wind Restriction Program, D. E. Muehlberger. Memo No. ACS-65-128, 3 May 1965 (General Dynamics/Convair).

3-4 Utlimate Loads for the AC-6 Payload Adapter, Nose Fairing, and Interstage Adapter to be Used for the AC-6 Flight Wind Restriction Report, P. W. Rogers. Memo No. ACS-65-106, 2 April 1965 (General Dynamics/Convair).

3-5 Tank Pressures for Use in AC-6 Flight Wind Restriction Procedure, T. E. Johnson. Memo No. SD-65-126-CEN, unpublished (General Dynamics/Convair).

3-6 Program Requirements Document for Centaur, F. Nickerson. Report No. PRD 800, 15 June 1964 (General Dynamics/Astronautics).

3-7 The COMBO Flight Program, H. B. Hilton. Report No. GD/A65-0967, 15 October 1963 (General Dynamics/Astronautics)

3-8 Guidance and Control Systems Requirements, W. F. Crocker and J. G. Largent. Report No. AY63-0071-6, 29 January 1963. (General Dynamics/Astronautics).

3-9 AC-6 Mass Properties, G. M. Huston. Memo No. CW65-60, 11 March 1965 (General Dynamics/Convair).

3-10 Monthly Configuration, Performance and Weight Status Report, A. E. Hunt. GD/C63-0495-21, 21 February 1965 (General Dynamics/Convair).

3-11 Monthly Configuration, Performance and Weight Status Report, Appendix B: (Trajectory and Performance Data), A. E. Hunt. Report No. GD/C63-0495-21, 21 February 1965 (General Dynamics/Convair).

3-12 Distributions and Total Vehicle Aerodynamic Coefficients for the Atlas/Centaur - Surveyor Vehicle, D. H. Lesney, Report No. GD/A-BTD64-062, 23 November 1964 (General Dynamics/Astronautics).

3-13 Digital Program Number 2464: FOLLY II, B. Appleby. Memo No. SD-63-191 SLV, 20 September 1963 (General Dynamics/Astronautics).

GD/C-BTD65-068
15 May 1965

DISTRIBUTION LIST

This report is to be distributed to the following people. Only those persons listed will receive notice of changes to this report in the event that a revision becomes necessary.

NASA/LeRC	(6)	
NASA/GDC	(2)	
NASA/GLO		
Space Tech Labs	(2)	
ETR		
R. C. Lynch	(2)	979-0
D. L. Sarokon	(2)	979-0
J. A. Schnabel	(4)	979-0
CENTAUR		
F. B. Anthony		966-5
M. R. Barlow		951-0

CENTAUR (Cont'd)		
R. Benzwi		952-3
W. S. Hicks		951-2
R. L. Holt	(8)	585-1
W. C. Jungemann		587-2
K. Kachigan		960-0
A. Kalitinsky		960-0
L. E. Lightbown		961-1
M. L. Male		951-3
R. E. Martin		585-0
C. D. Pengelley		585-1
A. C. Ward		966-4
R. S. Wentink	(2)	966-0

CONVAIR

GENERAL DYNAMICS | ~~ASTRONAUTICS~~